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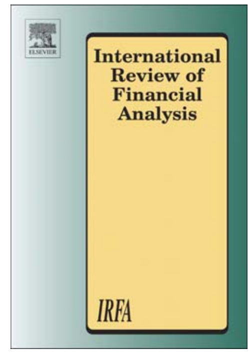

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Will the crisis “tear us apart”? Evidence from the EU

Vasileios Pappas[1]• Hilary Ingham[2]• Marwan Izzeldin[2] • Gerry Steele[2]

[1] University of Bath, Bath, BA2 7AY, UK

[2] Lancaster University, Lancaster, LA1 4YW, UK

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Abstract

We examine the synchronisation of the European Union (EU) financial markets before and during the 2007 global financial crisis. We use an Asymmetric Dynamic Conditional Correlation (ADCC)-GARCH framework to control for the time-varying correlations and a Markov-Switching model to identify regime changes. Our sample considers 27 EU nations for the period 2000-2011. For each nation we formulate several characteristics of the crisis such as, synchronicity, duration and intensity measures. We find that the more recent EU members had a lagged entry to the crisis regime, were less adversely affected, show higher correlation between their stock markets and have their credit scores being revised more frequently relative to established EU members. We also find that higher levels of sovereign debt and lower levels of industrialisation positively impact crisis duration and intensity. Our results refute the notion of uniform integration of EU financial markets as evident from the highly non-synchronised observed crisis experience among the EU members. As such, one-size fits all policies are likely to be ineffective.

Keywords: Contagion • Global Financial Crisis • Synchronisation • Intensity • Duration • ADCC-GARCH • European Union

JEL Classification: F36 • G15

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Corresponding Author: v.pappas@bath.ac.uk Tel: +44744 61 65 114 (Vasileios Pappas)

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1. Introduction

In the last two decades global financial markets have become highly integrated as evident by the intensity and coverage of the recent global financial crisis that originated in the US and resonated across the globe. European financial markets were amongst the hardest hit, partially due to their high interconnection with the US market, but also due to the increased integration within the European Union (EU).

The increased integration, efficiency and functionality of the financial system in the European Union ranks high within the EU economic agendas.[2] Indeed, these are seen as essential elements for the effective implementation of European Central Bank (ECB) economic policies (ECB, 2010). Till the recent past, high economic and financial integration have always been associated with prosperity and economic wellbeing. But is financial integration always desirable? On one hand it facilitates the functioning of a "Single Market", and acts as a medium via which financial instability may spread, manifested by excessive co-movements among asset prices which exceed those set by fundamentals. However, as weak economic fundamentals in one nation are brought into the spotlight by a financial crisis, investors may fear that other nations have similar traits; thus spreading financial contagion (Masson 1999). For example, towards the end of 2009, when problems in Greece were traced to severe fiscal/debt issues, the fear grew of similar scenarios within Italy and Portugal. Increased financial integration, liquid financial markets and new financial products (*e.g.*, credit default swaps), create transmission channels that allow contagion to spread more rapidly (Baele, 2005; Calvo, 1998). Although financial crises invite the search for evidence of financial contagion, it is more pertinent to question whether contagion is synchronised across the EU countries. Synchronisation would uphold the concept of the Single Market, whilst the idea of a "two-speed EU" would receive support if contagion were not synchronised.

In two consecutive phases between 2004 and 2007 the number of EU members[3] increased from 15 to 27. Although many of the 12 New Member States (hereafter NMS) display common economic features, others are disparate, either between themselves or compared to earlier EU members. For instance, the *per capita* GDP of Cyprus is twice that of Poland, while stock markets in the former satellite states of the Soviet Union, *i.e.*, the Central and Eastern Europe (CEE) nations, have very small market capitalisation. The popular representation of the hard-working North versus the lazy-South has also received much attention and highlights the lack of uniformity within the EU (Charlemagne, 2010). Despite such differences, some of the NMS committed themselves to the further step of integration by joining the Eurozone.

In recognising the varying degree of integration across EU nations, this paper examines the *experience* of a correlated-information channel type of financial contagion in light of the global financial crisis for the EU equity markets. The encompassing term *experience* refers to the existence, the synchronisation, the duration and the intensity of the financial contagion effects across the EU members.

For this purpose, we adopt an Asymmetric Dynamic Conditional Correlation (ADCC)-Markov Switching (MS)-GARCH model, which captures dynamic correlations and identifies regime change. The ADCC-GARCH allows the disentangling of negative and positive shocks in the volatility and/or correlation process (Gjika and Horváth, 2013), which makes an ideal candidate in the context of our study. The

[2] Financial integration is a priority for the Euro system. See the mission statement at: www.ecb.europa.eu.
[3] With its accession in July 2013, Croatia is the 28th member of the EU. It is however excluded from our study due to data limitations.

Markov-Switching Regime model of Hamilton (1994) provides an appealing framework to endogenously identify crisis events. Our sample consists of all the EU-27 nations' equity markets observed over the period 2000-2011. The sample size, range and nation classifications (*i.e.,* nations are arranged into six groups) allow us to draw more insights into the behaviour of the EU nations particularly during the period of market distress.

Our paper contributes to the extant literature in four ways. First, we present crisis transition date estimates for all EU-27 nations. Previous studies have either not studied the entire EU or have imposed an exogenous crisis transition date, implicitly assuming a singular crisis timing date for all. Second, we provide measures that gauge contagion duration and intensity. To the best of our knowledge the extant literature does not attempt to compare and contrast the contagion experiences of different countries. Third, we assess the impact of financial contagion on intra-EU integration. It has been suggested that co-movements are a reflection of integration within respective markets (Bekaert *et al.,* 2009). However, there is evidence (albeit limited) that such co-movements may be driven by intra-EU (as opposed to EU-wide) integration patterns; see for example, Gębka and Karoglou (2013). Fourth, and to the best of our knowledge, we provide the first integrated estimation on an extended data set of an ADCC-GARCH type of model with Markov-Switching models.[4]

Our main findings can be summarised as follows. In the broadest terms, the former EU members are affected earlier than the NMS. Where Core EU members are generally hit by the financial crisis around late July 2007, the effects reach the NMS more than a year later. The duration of the crisis has been more prolonged for the former EU members and the PIIGS (Portugal, Italy, Ireland, Greece and Spain) in particular, while for the NMS the duration has been significantly lower. Crisis intensity measures finds that the Core EU has been most adversely affected by the crisis. Overall, integration in financial markets seems to have been affected by the global financial crisis, while the results presented here suggest that differences between the EU nation groups may have widened.

This section is the first of six. Section 2 provides a brief outline of the literature. Sections 3 and 4 outline the data and the methodology. Findings are provided in section 5 which is followed by final conclusions.

2. Literature Review

2.1 From Integration to Contagion

Financial integration in the EU entered a new era in the years preceding the introduction of the single currency[5] with many studies documenting evidence of increased co-movements in national stock markets (Hardouvelis *et al.,* 2006; Baele and Inghelbrecht, 2010; Asgharian and Nossman, 2011 among others). In the early 21st century, stock markets in the EU members featured low volatility, high correlation, and reduced portfolio diversification benefits (Kim *et al.,* 2005; Baele and Inghelbrecht, 2009; Savva, 2009; Bekaert *et al.,* 2013).

[4] We are aware that univariate GARCH and Markov-Switching models have been estimated in a single step (Bauwens *et al.*, 2014; 2010; Augustyniak, 2014; Marcucci, 2005). Pelletier (2006) has offered an example of a DCC-GARCH with Markov-Switching.

[5] The Euro was launched on 1 January 1999 and replaced by 2002 the national currencies. For more information we direct you to https://www.ecb.europa.eu/euro/intro/html/map.en.html

Despite the benefits from financial integration during times of tranquillity, it brings detrimental effects during times of economic and/or financial instability. Homogeneous financial integration would propagate shocks more easily across the EU giving rise to increased correlations between stock markets in what has been generally termed as financial contagion (King and Wadhwani, 1990; Lee and Kim, 1993; Calvo *et al.*, 1996; Baig and Goldfajn, 1998). However, the asymmetric response of EU nations to external shocks has been indicative of the degree of heterogeneity in EU financial integration (Clayes and Vasicek, 2014). In that context, even if a crisis has been correctly anticipated, the presence, duration and intensity of financial contagion in every nation cannot be predicted. As such, it may be plausibly argued that from the two situations, the former may be preferable from certain viewpoints (*e.g.,* a regulator's) as the same "treatment" should be applied in all nations. Where some nations have been heavily exposed to financial contagion while others have weathered the storm may be trickier as it could give rise to further instability, dichotomy of suggested approaches at a policy-making level and inevitably discussions about a "two-speed Europe" (Gębka and Karoglou, 2013). Ultimately, and as argued in Yang *et al.,* (2003) and Bley (2009), financial integration differentials across time and EU-wide, may undermine the pursuit of the Single Market's ultimate goal.

The CEE group has occupied much of the literature testing for financial contagion over different phases of its integration with the EU/Eurozone. Early studies with a focus in the mid-90s conclude that integration levels amongst CEE stock markets and with the rest of the EU are low; see for example Kasch-Haroutounian and Price (2001) and Scheicher (2001). CEE stock markets have shown no signs nor symptoms of financial contagion (contrary to the EU-15) in light of earlier economic crises (*i.e.* the Mexican crisis of 1994, the East Asian crisis of 1997, the Russian collapse of 1998, the Brazilian devaluation of 1999 and the dot.com bubble of 2000), which has been attributed to their low degree of financial integration (Serwa and Bohl 2005; Gelos and Sahay, 2001). Following accession talks, the introduction of the single currency, financial openness and increased interest of foreign investors, integration in the CEE group increases and stock-market co-movements became more pronounced (Wang and Moore, 2008; Savva and Aslanidis, 2010; Syllignakis and Kouretas, 2011). CEE stock and bond markets exhibited financial contagion following the global financial crisis, as evidenced in the study of Chmielewska (2010).

2.2 Financial Contagion: Transmission Channels and Identification

Definitions of contagion may vary according to the transmission channel under study. Examples of transmission channels include the liquidity, the wealth effect, the risk-premium and the correlated-information. The liquidity channel is typically relevant to foreign financial institutions restricting liquidity in the host country as they adjust their positions in an attempt to meet with regulatory requirements and/or mitigate anticipated/realized losses in their home country (Acharya and Pedersen, 2005). Predatory trading can exacerbate the destabilizing effect of the liquidity channel (Brunnermeier and Pedersen, 2009). Contagion may be aggravated by wealth effect channels as traders with limited capacity for bearing risks liquidate their positions in the markets they operate (Kyle and Xiong, 2001). Such traders may rely on global variance risk premium, a proxy for economic uncertainty that can provide increased accuracy for the individual country return/risk predictability (Bollerslev *et al.*, 2014). For a detailed exposition of the contagion transmission channels we direct you to Pericoli and Sbracia, (2003). Implementation problems can arise due to the complex nature of some of these channels as argued in

Dimitriou *et al.,* (2013). The focus of this study is the correlated information channel, which posits that a shock in a financial market works as a signal, potentially affecting other financial markets.

From an identification viewpoint, contagion refers to the spread of financial disturbances among countries. Such disturbances can be represented as crisis probabilities; see for example Eichengreen *et al.,* (1999) where contagion is defined as a rise in the probability that a nation experiences a crisis given that a crisis exists in another nation. A complementary view emphasized by Bekaert *et al.,* (2005) is that contagion is identified by correlations beyond those that may be explained by economic fundamentals. Here, the challenge is to determine the fundamental factors, and whether to use observable variables or latent variables estimated by complex econometric techniques such as factor analysis.[6] Forbes (2001) suggests yet another definition: an increase in cross-market linkages following an economic shock in one nation. This "shift-contagion" (Forbes and Rigobon, 2002) highlights three main issues: international diversification; effectiveness of international institutions and bail-out funds; and propagation mechanisms (Billio and Caporin 2005). An advantage of the "shift-contagion" definition is that it makes use of correlation values (therefore integrates nicely with the correlated information channel) that are both intuitively straightforward to interpret and integrate well within financial integration framework (Bekaert *et al.,* 2009).

In the "shift-contagion" framework, testing for financial contagion typically amounts to tests of statistical significance between normal periods and crisis periods. In this manner, King and Wadhwani (1990) and Lee and Kim (1993) verify contagion across major stock markets following the 1987 US stock market crash.[7] This approach has also been applied in the wake of the 1994 Mexican crisis for stock and bond markets (Calvo *et al.* 1996). In similar fashion, Baig and Goldfajn (1999) investigate the contagion effects of the 1997 East Asian crisis on stock and bond markets, currency exchange values and interest rates.

A drawback of the "shift-contagion" methodology relates to the heteroskedasticity induced bias on financial contagion tests (Forbes and Rigobon, 2002). However, the innovation of multivariate GARCH models[8] that produce time-varying correlation coefficients has surpassed these problems and re-energised interest in financial contagion studies (Engle 2002; Tse and Tsui, 2002). Much of this research is focused on exchange rates (Khalid and Rajaguru, 2005), bond markets (Coudert and Gex, 2010) and stock markets (Chiang *et al.,* 2007). From their investigation of nine East Asian exchanges (1990 - 2003) using a DCC-GARCH framework the latter authors find evidence of contagion after the 1997 Asian financial crisis. Cho and Parhizgari (2008) obtain similar findings from a larger sample of 14 nations. Yiu *et al.,* (2010) and Naoui *et al.,* (2010) find evidence of contagion between the US and East Asia for the 1997 East Asian, the 2000 dot.com and the 2007 financial crises. Kenourgios *et al.,* (2011) verifies financial contagion from the crisis country to a set of emerging and developed countries for the 1997 East Asian

[6] For financial contagion to be verified through this technique there should be statistically significant evidence of correlation in the model's residuals. However, the identification of financial contagion may be inversely related to the models' performance, which could explain why Baele and Inghelbrecht (2010) fail to find contagion with their optimal model, but document contagion evidence once a more restricted model is used.

[7] On the October 19th 1987 the Dow Jones fell 22.6%, the largest one day fall to date.

[8] Prior to the introduction of Dynamic Conditional Correlation (DCC) models, correlations were either assumed to be time-invariant or their estimation would suffer from the 'dimensionality curse', as witnessed by VEC and BEKK models, as described in Engle and Kroner (1995). As a consequence, most empirical work has been either: a) restricted to a limited number of nations, or b) assumed time-invariant correlations so that estimation parameters are kept low. Several studies have looked at contagion across a limited number of nations to avoid the aforementioned econometric problems. For instance, Hamao *et al.* (1990) test for contagion between Japan, the UK and the US in the wake of the 1987 US stock market crash, while Edwards and Susmel (2003) focus on how the Mexican devaluation of 1994 was manifested upon the bond markets of Argentina and Chile.

crisis, the 1998 Russian crisis, the 2000 dot.com and the two Brazilian crises in 1997-98 and 2002. The global financial crisis has been a focal point with several studies investigating contagion in a cross-country (Suh, 2015; Ludwig, 2014; Dimitriou *et al.*, 2013; Kalbaska and Gatkowski, 2012), a cross-industry (Kenourgios and Dimitriou, 2015) or a combined basis (Bekaert *et al.*, 2014) focusing on stock, CDS and implied volatility markets among others.[9]

3. Data and Descriptive Statistics

We use daily stock market indices from Datastream for 27 EU nations from 1st January 2001 until 27th September 2011, giving a sample of 2,800 observations.[10] For each of the indices, the continuously compounded percentage returns are calculated as $r_t = \log\left({p_t}/{p_{t-1}}\right) \times 100$, where p_t is the closing price at day t.[11] Initially the EU-27 nations are divided into two groups corresponding to the EU-15 and the NMS. Subsequently each of these broad groups is split into three sub-groups as follows. The EU-15 sub-groups are: *Core EU* (Austria, Belgium, France, Germany, Luxembourg, Netherlands and the UK), *Scandinavian* (Denmark, Finland and Sweden) and *PIIGS* (Portugal, Italy, Ireland, Greece and Spain). The Scandinavian nations share a common history and significant trade linkages. Further, Denmark and Sweden opted not to join the Eurozone. Recent discussions relating to competitiveness, fiscal deficits and public debt problems underpin the PIIGS group of nations, see for example, Gębka and Karoglou (2013). The NMS sub-groups are: *Baltics* (Estonia, Latvia and Lithuania) and the *Recently Acceded Member States (RAMS)* which are divided into *RAMS I* (Czech Republic, Hungary, Poland and Slovenia) and *RAMS II* (Bulgaria, Cyprus, Malta, Romania and Slovakia). The *Baltics* are linked by their proximity, common history and common ownership of stock markets by the OMX. *RAMS I* and *RAMS II* are defined by the three-year difference in the starting dates of their negotiation talks with the EU. Table 1 presents the group classifications together with the equity indices under consideration.

[Table 1 here]

Table 2 summarizes key financial and macroeconomic indicators for the EU nations that provide *prima facie* evidence of heterogeneity. Stock market capitalization - a measure of the development of domestic financial markets - is reported as a percentage of GDP in 2010. Overall, financial markets are more developed in the EU-15 compared to the NMS with capitalisation figures ranging between 183.55% for Luxembourg and 4.66% for Slovakia. The results are consistent with the efficient market hypothesis[12] for a majority of the EU-15 nations but not for the NMS. This can be partially attributed to the shorter history

[9] We are aware of the existence of other techniques to estimate contagion. The DCC approach is similar and compares rather well to other techniques available in the literature. Moreover, the DCC approach is easy to implement and interpret.
[10] Complete coverage for some of the New Member States is not available prior to this date.
[11] Several studies are mindful of an induced bias when stock markets operate during different trading hours (Kahya, 1997; Burns et al., 1998; Martens and Poon, 2001). This is particularly relevant when dealing with countries across a large variety of time zones (e.g., UK, US, Japan) and/or countries operating a different business week (for example, the business week in the Arab Gulf countries is Sunday to Thursday). Jondeau and Rockinger (2006) lag US returns to accommodate the different trading hours of US and European markets. Similarly, Kenourgios et al. (2014) use two-day moving averages. However, this becomes of little concern as all EU stock markets operate within a maximum of a two-hour difference. To accommodate for time differences, we use of daily closing prices as suggested in Gębka and Karoglou (2013).
[12] We apply the Wald-Wolfowitz test (also known as runs test), first used by Fama (1965) to test the weak form of the efficient market hypothesis. The null hypothesis states that each element in a "run" is independent and identically distributed. Failure to reject the null provides support for the efficient market hypothesis.

of financial intermediation in the majority of the NMS. Their stock markets were developed with their transition from communism in the early 1990s. In terms of the macroeconomic environment, there are signs of recovery from the crisis towards the end of our sample period, with Luxembourg recording positive annual GDP growth (3.52%). By contrast, signs indicative of poor financial conditions and on-going problems are still evident in Finland (-8.20%). The PIIGS show greater similarity with the NMS in certain respects. For example, stock market capitalisation is lower in the PIIGS compared to the Core-EU and the Scandinavian groups, while Italy and Portugal were the only nations of the group to record a positive GDP growth in 2010.

[Table 2 here]

Table 3 provides stock market descriptive statistics for the EU-27 nations for the sample period. In general, returns are higher for the NMS compared to the EU-15. The PIIGS group had the worst performance, with an average return of -0.025%, with the figure for Greece being the lowest at -0.052% and Spain the highest at -0.003%. Similarly, the Core EU group had an average daily return of -0.002%, with the highest and lowest occurring in Germany (0.043%) and the Netherlands (-0.029%) respectively. By contrast, the groups constituting the NMS enjoyed positive average returns ranging from 0.016% (RAMS II) to 0.043% (Baltics). The annualized volatility and value-at-risk (VaR)[13] measures reflect the turbulent economic environment. For instance, VaR classifies the financial market of Germany (Luxembourg) as being the least (most) risky. Note that, at the outbreak of the financial crisis, the Luxembourg stock market index lost about 85% of its value, possibly a reaction to the investment re-shuffling of a number of money market funds domiciled in the nation due to the favourable tax and legal environment (KPMG, 2011; PwC, 2008).

[Table 3 here]

4. Methodology

This section outlines the estimation techniques adopted in this study. We consider an asymmetric dynamic conditional correlations (ADCC) GARCH model, similar to Gjika and Horváth (2013). This model accounts for both the time varying nature and asymmetry of the cross-movement of volatilities. To identify regime changes and crisis transition dates we use a Markov-switching framework, following Mandilaras and Bird (2010). This framework is incorporated within the ADCC-GARCH estimation, similar to Marcucci (2005).[14] Therefore our general model may be termed as an ADCC-MS-GARCH. We construct measures of crisis synchronicity, duration and intensity. Cerda (2009) provides several measures of crisis duration, albeit in a different context, which are notionally aligned to those we report. Although there has been discussion on the extent of crisis synchronicity and intensity - see for example Claeys and Vasicek, (2014); Gębka and Karoglou, (2013) - ours is the first attempt to quantify these concepts in a financial contagion framework. We provide extensive analysis of the conditional correlation measures from two viewpoints; an EU-wide and an intra-EU. These measures enable us to assess the impact of the

[13] Value at Risk (VaR) estimates the worst 1-day ahead loss at a given confidence level. VaR is calculated as the 5th percentile of the stock market returns, thus avoiding any assumptions pertaining to the normality of the return distribution.

[14] Univariate models of the DCC-GARCH are essentially Markov-Switching GARCH models. These generally suffer from the "path dependency" problem. One way to deal with this issue is for their estimation to be done through certain modifications on the likelihood function (see for example Gray, 1996; Glynn and Haas, 2004 and Klaassen, 2002). Other methods include the use of GMM methods (Francq and Zakoian, 2008), Bayesian (Bauwens *et al.,* 2010; 2014) or "quasi"-Bayesian techniques (Augustyniak, 2014).

financial crisis on the dynamics of co-movements between EU stock markets, and whether these are due to the respective market's integration with the rest of the EU, or due to regional, intra-EU integration.

4.1 Dynamic Conditional Correlation

Dynamic Conditional Correlation (DCC)-GARCH models were introduced separately by Engle (2002) and Tse and Tsui (2002), with the two approaches differing in the parameterisation of the conditional correlation matrix. Subsequent extensions of DCC-GARCH models are of two kinds. The first is in the volatility modelling phase where the univariate GARCH has been superseded by models that account for asymmetries (EGARCH), long-memory (FIGARCH) and regime changes (MS-GARCH). The second relates to the DCC estimator itself, with the corrected DCC-GARCH model proposed by Aielli (2013) providing an alternative, asymptotically unbiased, estimator.[15] Further extensions include the asymmetric DCC (ADCC) model, which allows for asymmetric effects to impact the conditional correlations (Cappiello *et al.*, 2006).

In general, the estimation of an ADCC-GARCH type of model consists of three phases (Engle, 2002). In the first phase, univariate GARCH models are fitted to the asset returns. In the second phase, the unconditional correlation and covariance matrices of both standardised returns and negative standardised returns are estimated. The third phase consists of a quasi-maximum likelihood estimation procedure for the conditional correlation dynamics.

To outline the framework consider a $T \times 1$ vector of asset returns in which, r_t is normally distributed with mean zero and variance h_t

$$r_t | \mathcal{F}_{t-1} \sim N(0, h_t) \quad (1)$$

$$h_t^2 = \omega + \sum_{i=1}^{q} \boldsymbol{A}_i \, u_{t-i}^2 + \sum_{j=1}^{q} \boldsymbol{B}_j \, r_{t-j}^2 \quad (2)$$

Where $\boldsymbol{\mathcal{F}}_{t-1}$ is the information set at time $t-1$, and the variance process is characterised by a GARCH process.

For the $N \times T$ matrix of asset returns the time-varying covariance matrix $\boldsymbol{H}_t$ is defined as a product of time-varying standard deviations and time-varying correlations as follows:

$$\boldsymbol{H}_t = \boldsymbol{D}'_t \boldsymbol{R}_t \boldsymbol{D}_t \quad (3)$$

where

$$\boldsymbol{D}_t = diag\{h_{1t}^{1/2}, \ldots, h_{Nt}^{1/2}\} \quad (4)$$

To incorporate asymmetries in the correlation dynamics Cappiello *et al.*, (2006) modify the conditional correlation equation of Engle (2002) to the one given below:

[15] Note though that the bias of the DCC-GARCH estimator is negligible even in large samples (Caporin and McAleer 2014).

$$\boldsymbol{Q}_t = \left(1 - \sum_{m=1}^{M} a_m - \sum_{n=1}^{N} b_n\right)\overline{\boldsymbol{R}} - \sum_{k=1}^{K} g_k \overline{\boldsymbol{N}} + \sum_{m=1}^{M} a_m(\varepsilon_{t-m}\varepsilon'_{t-m}) + \sum_{k=1}^{K} g_k(n_{t-k}n'_{t-k}) + \sum_{n=1}^{N} b_n \boldsymbol{Q}_{t-n} \tag{5}$$

where n_t takes the value 1 when $\varepsilon_t < 0$, zero otherwise, representing therefore bad news. For the matrix $\boldsymbol{Q}_t$ to be positive definite, a set of restrictions is imposed. These restrictions require that: i) $a_m > 0$; ii) $b_n > 0$; iii) $\tau_k > 0$; iv) $\sum_{m=1}^{M} \alpha_m + \sum_{n=1}^{N} b_n + \eta \sum_{k=1}^{K} \tau_k < 1$ and $\eta =$ maximum eigenvalue$[\overline{\boldsymbol{R}}^{-1/2}\overline{\boldsymbol{N}}\overline{\boldsymbol{R}}^{-1/2}]$ is estimated from the data. A rescaling of $\mathbf{Q}_t$ ensures that the correlation matrix is well-defined with unitary values along the main diagonal and with each off-diagonal element ranging in absolute value between zero and one (Silvennoinen and Teräsvirta 2008). The formula for the rescaling of correlations is:

$$\boldsymbol{R}_t = (\boldsymbol{I} \circ \boldsymbol{Q}_t)^{-1/2}\boldsymbol{Q}_t(\boldsymbol{I} \circ \boldsymbol{Q}_t)^{-1/2} \tag{6}$$

where $\boldsymbol{I}$ is the identity matrix and $\circ$ denotes the Hadamard product.

For the multivariate part of our setting (the univariate is described in the next section), we adopt an ADCC (1, 1, 1), following Gjika and Horváth (2013) among others. This is given by:

$$\boldsymbol{Q}_t = (1 - a - b)\overline{\boldsymbol{R}} - g\overline{\boldsymbol{N}} + a(\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}) + g(\boldsymbol{n}_{t-1}\boldsymbol{n}'_{t-1}) + b\boldsymbol{Q}_{t-1} \tag{7}$$

4.2 Regime Change and Markov-Switching Models

Common to financial contagion studies adopting a DCC-GARCH framework, is the assumption of an exogenous crisis date. Although this may be plausible for narrow studies, it may be quite restrictive in a multi-nation EU. Several studies have suggested alternative techniques to ameliorate this problem. For example, Olbrys and Majewska (2014) divide market states into “up” and “down” markets in an attempt to assess the timing of crisis periods for the CEE stock markets. Dividing the volatility series according to the timing of structural breaks prior to testing for financial contagion is followed in Blatt *et al.*, (2014).

Markov-switching models, introduced by Hamilton (1994), permit the endogenous estimation of crisis dates, while determining the prevalence of one of two regimes[16]; a tranquil, relatively stable regime of the economy and a turbulent one that intuitively corresponds to a crisis regime. Mandilaras and Bird (2010) use a Markov-switching in a VAR setting to detect contagion effects in the Exchange Rate Mechanism (ERM) for 9 countries over the period 1978 - 1993. Baele (2005) find that volatility spillovers to 13 European stock markets - from within the EU and the USA over the period 1980-2001 - have been intensified during the crisis regimes, which are identified via a Markov-switching model.

A Markov-Switching set-up allows transition probabilities to be estimated, from one state of the economy to another.[17] Markov-Switching models rely on the data to identify the timing of the shift.[18] Typically a

[16] Markov-switching models can be estimated for more than two regimes. However, as the number of regimes increases the computational burden gets more pronounced without a clear benefit in terms of interpretation.
[17] The Markov-Switching model of Hamilton (1994) belongs to the family of non-linear models which includes SETAR (Tong 1990) and LSTAR models (Teräsvirta 1994). For a broader discussion of these models the reader is directed to Tsay (2010).

latent state variable (s_t) is used to denote which of the M states the economy is in period t with $s_t = m\ ;\ m = 1, \dots, M$. With a typical Markov-switching model for a crisis and a calm regime, regime specific means and volatilities may be written as:

$$y_t = \omega_m + \sigma_m \varepsilon_t;\ \ \varepsilon_t \sim iidN(0,1) \tag{8}$$

with the regime transition probabilities are given as:

$$Pr(s_t = m_i | s_{t-1} = m_j);\ i, j = 0,1 \tag{9}$$

In our case we adopt the Markov-Switching GARCH (1,1) as our univariate model:

$$r_t = \theta_{s_t} + u_t, u_t \sim iid\left(0, h_{t,s_t}\right) \tag{10}$$

$$h_{t,s_t}^2 = \omega_{s_t} + a'_{s_t} u_{t-1}^2 + \beta'_{s_t} h_{t-1}^2 \tag{11}$$

The Markov-Switching GARCH (1,1) model outlined above is the first phase of the multivariate ADCC-GARCH model we utilise and allows for all parameters to depend on the (latent) state of the economy.[19]

4.3 Synchronization, Duration and Intensity Measures

A way to compare the financial crisis experience within the EU countries is to look at crisis synchronisation, duration and intensity measures. To assess the synchronisation of the financial crisis, we compare the estimated crisis transition dates for each individual EU nation with a benchmark date. As benchmark, we utilise the 1/8/2007 which corresponds to the onset of the US sub-prime crisis (Hwang *et al.*, 2010; BIS, 2009).[20]

Synchronization of the onset of the crisis is expressed in days and is given as:

$$Sync_i = T_{c_i} - T_{c_{bench}} \tag{12}$$

where i denotes the nation, T_{c_i} denotes the crisis transition date for each nation and $T_{c_{bench}}$ corresponds to the crisis benchmark date. Positive (negative) values indicate a lag (lead) in the transition, relative to the benchmark date for the particular country.

The duration of crisis is measured as the time that a nation has spent within the crisis regime, as identified by the Markov-switching model. It is expressed in days and as a percentage and given as:

[18] Strictly speaking, a Markov-switching model employs a state variable which is governed by a first-order Markov chain; thus leaving no room for explanatory variables. The more generic time-varying transition probability models may include explanatory variables to determine the regime of the economy at the cost, however, of greater complication (Filardo, 1994).
[19] It is also possible to allow for different regimes in the conditional correlation process (i.e., the ADCC phase), see for example Pelletier (2006) and Cappiello *et al.*, (2006) for approaches with Markov switching regimes and exogenously defined structural breaks respectively.
[20] Changing the benchmark date to the collapse of the Lehman brothers (15/9/08), which corresponds to the end of the 1st phase of the global financial crisis (BIS, 2009) does not challenge our qualitative findings.

$$Duration\ (days)_i = \sum_{t_i=T_{c_i}}^{T} t_i\,|s_{t_i} = 1 \tag{13}$$

$$Duration\ (\%)_i = \frac{\sum_{t_i=T_{c_i}}^{T} t_i\,|s_{t_i} = 1}{\sum_{t_i=T_{c_i}}^{T} t_i} \tag{14}$$

where $s_t = 1$ denotes the crisis regime.

Intensity of financial crisis is defined as the logarithmic change in the average volatility level between the crisis and calm regimes in the period following the crisis transition date for each nation. Intensity is expressed as a percentage where a higher (lower) value denotes a more (less) pronounced impact of the financial crisis for the particular nation. Intensity is expressed as a percentage and is given as:

$$Intensity_i = \ln\left(\frac{\sum_{t_i=T_{c_i}}^{T} h_{t,i}\,|s_t = 1 / \sum_{t_i=T_{c_i}}^{T} t_i\,|s_{t_i} = 1}{\sum_{t_i=T_{c_i}}^{T} h_{t,i}\,|s_{t_i} = 0 / \sum_{t_i=T_{c_i}}^{T} t_i\,|s_{t_i} = 0}\right) \tag{15}$$

where $h_{t,i}$ denotes the conditional volatility.

4.4 Financial Contagion Measures

Estimates obtained from the ADCC-MS-GARCH model are used to assess the financial contagion in the EU. We construct two correlation indicators that capture EU-wide and intra-EU integration. The EU-wide measure is calculated as the average of the conditional correlation coefficients between a respective nation and all other nations in the sample. For the intra-EU measure, each nation group is considered in isolation; therefore only conditional correlation coefficients among nations in their respective group are considered. The two conditional measures are each given as:

$$EUwide_{i,t} = \sum_{i=1}^{N}\sum_{j=1}^{N} \tilde{\rho}_{ij,t}/N\ \ \forall\ i \neq j \tag{16}$$

$$intraEU_{i,t} = \sum_{i^*=1}^{N^*}\sum_{j*=1}^{N^*} \tilde{\rho}_{ij,t}/N\ \ \forall\ i \neq j \tag{17}$$

where $\tilde{\rho}$ is the estimated conditional correlation coefficient from the ADCC model, N is the cross-sectional dimension, N^* denotes the nations in each of the nation groups.

5. Results and Discussion

Table 4 reports the estimated coefficients, standard errors, goodness-of-fit statistics and transition probabilities for the univariate MS-GARCH models for all the EU-27 nations of the sample. Estimated coefficients are highly significant.[21] The estimated coefficients obtained under the two regimes (calm / crisis) reveal varying volatility dynamics. Overall the non-linear framework provides a good approximation of volatility, as evidenced by the linearity test. Table 5 presents the estimated coefficients of the ADCC model, which are statistically significant. The significantly positive estimate of the asymmetric term, the information criteria and a likelihood ratio test suggest that the ADCC has a slightly better fit than the standard DCC, as it captures asymmetric effects in the conditional correlations.[22]

[Table 4 around here]

[Table 5 around here]

Panel A in Figure 1 shows the evolution of stock price indices for France and the Czech Republic, which we use as illustrative cases for the EU-15 and the NMS nation groups respectively.[23] In the early 2000's, the French stock market experienced a steep downward trend following the burst of the dot.com bubble. Thereafter, an upward trend is evident until the global financial crisis, after which the stock market has fallen sharply. A recovery phase is evident post 2009 but the index remains below pre-crisis levels. The stock market in the Czech Republic shows similar patterns with the exception of the downward trend that followed the dot.com crisis. Panel B, displays the calm / crisis regimes identified by the Markov-Switching model for the volatility in the two nations' stock market indices. The shaded areas represent periods of turmoil with marked differences in their timing and duration, constituting evidence in favour of varying crisis profiles. Figure 2 shows the crisis transition date for all EU-27 nations. The figure clearly shows a wide disparity in the transition dates, which spread over 623 days, across the different nations.

[Figure 1 and 2 here]

5.1 Synchronization, Duration and Intensity of the Crisis

Table 6 reports the crisis experience indicators for every nation and nation group in the sample. Specifically, column II reports the crisis transition dates estimated from the Markov-switching models. Columns III – VI report the calculated measures of crisis synchronization, duration and intensity. Columns VII – VIII relate to sovereign credit rating score revisions, showing the date immediately pre and post the crisis transition date.[24] Columns IX – X show the lead/lag between the credit score change and the crisis transition dates.

[Table 6 here]

A. Synchronisation

[21] As a robustness check we implement a MS-EGARCH(1,1) which accounts for asymmetries in the volatility process. The results (which are not reported) bring no definite improvement over the more parsimonious MS-GARCH(1,1). Hence, for consistency purposes, we proceed with the MS-GARCH(1,1) specification for all nations.

[22] As a robustness check, we have cross-checked the crisis transition dates from the Markov Switching framework with those provided by a Zivot-Andrews test (1998) on the conditional volatility of the equity indices. The results show that the dates provided by the two approaches are closely aligned.

[23] Owing to space limitations we only report two illustrative graphs for two countries, one from the EU-15 and one from the NMS groups. Graphs for all nations are available upon request.

[24] Credit rating scores are obtained from Fitch ratings. The majority of the updates relate to downgrades or to negative switches in the outlook.

Our results refute the notion that all nations experienced a synchronised transition into a crisis regime. One interpretation is that some EU countries were affected with a significant delay by the global financial crisis (GFC). A second interpretation is that, although these countries were directly unaffected by the GFC, they were hit when the effects of the direct impact spread to their economic sectors. The Bank for International Settlements (BIS, 2009) and the Federal Reserve Board of St. Louis (2009) have provided official timelines that place the GFC in four phases.[25] The vast majority of the estimated crisis transition dates fall into the first period. Therefore, we believe that the first interpretation receives empirical support from our data.

The EU-15 nations, the most synchronised group, enter the crisis regime with an average lag of 8 days relative to the crisis transition date benchmark.[26] Conversely, the NMS lags by 165 days and features a wider dispersion between group members. The latter, may relate to their belated entry to the EU and their lower degree of integration. For example, the RAMS I and II groups show a difference of around 107 days in their synchronization of transition to the crisis regime. The non-synchronized transition among Core EU nations is best illustrated by Germany and Luxembourg cases. Relative to the Core EU group average, Germany's entry to the crisis regime lags by 97 days whereas Luxembourg's leads by 153 days. The different orientation of the two economies, with Luxembourg primarily focused on the financial sector, while industry accounts for a large proportion of Germany's GDP may be driving these results. The low stock market activity could be an important factor for the non-synchronisation among the NMS; thereby causing the transmission of shocks to take longer. The cases of Poland (lags by 5 days) and Latvia (lags by 412 days) could further highlight this point as the former's economy is the largest of all NMS, while Latvia is one of the smallest.

B. Duration and Intensity

The duration measures further illustrate the differential crisis experiences of the EU-27 nation groups, with the EU-15 staying for an average of 910 days (92.07%) in crisis regime, as opposed to the 608 days (85.43%) for the NMS, which corresponds to a significantly prolonged crisis duration. The intensity measure also confirms that the severity of the financial crisis has been stronger in the EU-15 than the NMS, as evident from the higher average intensity values (67.10% vs 57.76%) respectively. These findings may be attributed to the increased financial integration of the EU-15 compared to past crises, particularly in respect of the Eurozone, which allows for faster propagation of economic and financial shocks. Nevertheless, the finding provides *prima facie* evidence of a "two-speed EU" with heterogeneous levels of financial integration, which calls for enhanced policies that cater for the distinctive features of the EU nations in periods of crisis. The Scandinavian group weathers the crisis better than both the Core EU and the PIIGS as evident by the lower intensity values. The severity of the crisis in the PIIGS group

[25] The four phases of the GFC are: i) Initial financial turmoil (1/8/2007 – 15/9/2008); ii) Sharp financial market deterioration (16/9/2008 – 31/12/2008); iii) Macroeconomic deterioration (1/10/2009 – 31/3/2009); iv) Stabilisation and tentative signs of recovery (1/4/2009 – 1/11/2009) and have been used in Baur (2012) and Kenourgios (2014) among others. The four phases of the GFC do not cover the ongoing European sovereign debt crisis.

[26] It would be interesting to compare whether this time lag increased/decreased compared to previous crises, however most of the research is not directly comparable for several reasons. Not all crises are directly comparable as they could be regional specific (i.e., 1997 East Asian) or not directly linked to economic/financial characteristics (i.e., 9/11 terrorist attacks). Furthermore, many studies look at spillover effects following a crisis, usually around financially developed countries (see for example, King and Wadwani, 1990).

may be attributed to investors penalising markets with poor macroeconomic fundamentals, policies and institutions (Bekaert *et al.*, 2014). The crisis duration and intensity for Greece is interesting insofar as the country records the highest duration (97.43%) and lowest intensity (60.03%) value among the PIIGS group. In Greece the global financial crisis brought to surface chronic debt, fiscal and structural problems. However, unlike Ireland where the financial and banking sectors were hit, in Greece these sectors were relatively unaffected owing in part to the low exposure to securitisation products. Furthermore, the Greek stock market has lower capitalisation than the EU average, and is less interconnected even within the PIIGS group (see also section C) with limited presence of institutional investors. The high exposure of Austria and Belgium to the NMS, as identified in Árvai *et al.*, (2009), may be a reason for their relatively high crisis intensity score within the Core EU group.

The RAMS II group has weathered the crisis better than the RAMS I group, as evidenced from the lower intensity values. However, the duration of the crisis shows no significant differences between the two groups, albeit there are a few exceptions of nations residing longer in the crisis regime. Cyprus, for example, records the highest crisis duration among the NMS. There are many economic reasons that could explain differentiated responses to the crisis at the nation group level. Nations in the RAMS I group are in a better economic position relatively to those of the RAMS II with respect to the size of the economy (GDP figures are $88.27bil vs $25.03bil respectively) and living standards (around $2,500 difference in GDP *per capita*). The delayed start (*i.e.*, by approximately 3 years) of the EU accession talks of the RAMS II group could also be a contributing factor.

C. Unified Crisis Performance

The synchronisation, duration and intensity measures reflect different facets of a nation's unified crisis performance (UCP). As such the information they contain, if combined, can provide a systematic ranking about how EU-27 nations fared during the crisis. To achieve this we consider a principal component analysis in two phases. In the first phase we define a single principal component (UCP_A), scaled between zero and one, where higher values indicate nations that fared worse during the crisis. In the second phase and in a similar manner, two principal components (UCP_{B1}, UCP_{B2}) are retained.[27]

[Figures 3 and 4 here]

Figure 3 ranks the EU-27 nations ranking according to the (UCP_A) indicator. At the extreme ends are Luxembourg and Malta, with the former being the worst affected by the global financial crisis. The figure also marks a clear separation between the EU-15 and the NMS groups with the former in the leftmost part of the graph. Figure 4 illustrates the association of the nations in terms of the (UCP_{B1}, UCP_{B2}) indicators. Of interest are the Core EU and the PIIGS groups that appear clustered together (top-right), illustrating that the crisis hit them in a similar manner. The lower association of Greece relatively to the other PIIGS, which was highlighted previously, is here more evident. The NMS are high variable with regards to the UCP as evident by their random scatter. Other notable patterns are the intense degree of crisis exposure in the RAMS I compared to the RAMS II group.

[27] The first principal component accounts for 51.66% of the total variance, while with a second the total variance explained reaches 89.35%. For the case of the two principal components we apply an orthogonal varimax rotation that facilitates the interpretation of the components. The first component explains synchronisation/intensity of the crisis, while the second component captures the crisis duration. Principal component analysis has been advocated in Bekaert et al. (2014) among others.

D. Credit Rating Scores

Do changes in credit rating scores match the crisis transition dates of the different nations? Table 6 shows that credit rating scores responses vary across nation groups. Credit rating scores remain unchanged for most of the Core EU and the Scandinavian nations. By contrast, the PIIGS, the Baltics, the RAMS I and II groups show credit score downgrades. The lag between the credit score downgrades and the crisis transition dates range between 210 – 450 days, meaning that downgrades could potentially act as an upcoming crisis indicator. Subsequent downgrades that could warn about the severity of the crisis occur with a higher delay. For example, the PIIGS were downgraded, on average, around 750 days after they entered the crisis which could have, in part, affected the awareness of the severity of the crisis, a fact evidenced by the lack of any meaningful relation between credit rating score changes and the crisis duration and intensity measures. By contrast, for the NMS credit scores are more responsive, ranging between 30 – 300 days. The reason for this difference may be due to the fact that NMS were monitored more closely (between 180 – 365 days gap between last update of credit rating score and the crisis transition date) than the EU-15. One possible explanation is that new entrants' economies are not a familiar territory for the credit rating agencies.

5.2 Correlation and Contagion Effects

Table 7, Panel A, Columns II – III show the EU-wide average conditional correlations for the pre-crisis and crisis periods respectively. Columns IV and V report the median and mean changes between the pre-crisis and post-crisis periods of the two correlation indicators per nation group. Column VI shows the standard deviation of the correlation changes in every group. Column VII lists the significance *t*-test values for the mean change between the pre-crisis and crisis periods. Table 7, Panel B reports the same statistics for the intra-EU average conditional correlations. As can be seen from the table, the results are mixed.

[Table 7 here]

The EU-wide correlations are higher for the EU-15 than the NMS, possibly due to the longer presence of the former nations in the European Union and the Eurozone. The intra-EU correlations show that nations in the Scandinavian group are the most interconnected, while those in the RAMS II group are the least.

During the crisis all the nation groups - but the RAMS II - show evidence of an increase in the EU-wide correlations, verifying financial contagion financial contagion for the respective groups. These results are in line with the studies of (Syllignakis and Kouretas, 2011), which verify adverse crisis effects and the presence of contagion for the CEE region, and also the vulnerability of emerging markets to crises (Kenourgios and Padhi, 2012). Intra-EU correlations also increase and indicate the presence of financial contagion within the respective country groups. Comparing the magnitude of the EU-wide and the intra-EU correlation changes is suggestive of a varying degree of contagion across the nation groups. Therefore the crisis has had a differentiated impact upon the EU, a finding that is in line with Gębka and Karoglou (2013), who take a more globalised perspective.

The evidence shows that the Scandinavian, the PIIGS and the Baltic groups become notionally aligned to financial markets beyond their respective groups, potentially showing evidence of a higher interconnectedness to the EU as evidenced by the relatively larger increase in the EU-wide compared to the intra-EU measure. For the Scandinavian group, the higher alignment with stock markets outside of their group could relate to the important trade linkages they enjoy with other EU nations. For the Baltic group it could be in part attributed to the economic instability in Latvia, the great penetration of foreign banks and the close financial links with the Scandinavian countries (Estonia, 2013). For the PIIGS group it may be plausibly linked to the EU actions (*e.g.*, bailouts, financial support packages, economic monitoring) with respect to these crisis-hit countries.

By contrast, the opposite is shown for the Core EU and the RAMS groups where the stock markets show evidence of retrenching into national borders. This is likely to be a story of two extremes, where on the one hand the nations belonging to the Core EU group have well-established financial centres, share a great commitment to the "European identity" (Eurobarometer, 2013) and act as an economic bellwether for the rest of the EU. On the other hand, for the RAMS I and II groups the explanation may rest with their lesser integration (partly attributed to their recent acceptance) with the EU-15 (*i.e.*, in respect of labour markets, retail markets and financial markets) and their weaker sense of "European identity" (Eurobarometer, 2013).

5.3 Crisis Intensity and Economic Indicators

In the pre-crisis period, investors were driven by the low-interest rate environment. In pursuit of higher yields they switched from developed to developing markets and, within the EU, from the so-called "core" (*i.e.*, EU-15) to the periphery (*i.e.*, NMS). The global financial crisis brought to the surface the risks associated with enhanced rewards. This led investors to rebalance their portfolio positions, shifting back to the perceived safety of the "strong" states (*i.e.*, Germany, the Netherlands). Under duress, market participants compared the relative strength of the EU states, and reacted accordingly. In doing so, they gave support to the notion that the intensity of a nation's crisis experience is related to the quality of its economic fundamentals (Bekaert *et al.*, 2014). As "stronger" economies weathered the crisis, others were targeted as the weaker links in the chain.

We consider a Spearman rank correlation measure to analyse the impact of economic indicators on the unified crisis performance (UCP) indicator. Our set of macroeconomic variables includes: i) the current account balance as a percentage of GDP; ii) central government debt as a percentage of GDP; iii) the ratio of total labour costs to real output – reflecting cost competitiveness; iv) the real effective exchange rate – as a proxy for competitiveness; v) the percentage of value added to GDP by industrial and manufacturing activities – as a proxy for industrialization; vi) a Eurozone (single currency) dummy. Annual data are sourced from the IMF, the World Bank and OECD for the period of the study. We use the average levels of these measures over the full study period.

Table 8 reports the estimated correlation coefficients and diagnostics from our analysis. The results show industrialisation, the Eurozone dummy, current account balance and the real effective exchange rate to be statistically significant with the expected signs. Low levels of current account debt, real effective exchange rate and a higher degree of industrialisation contribute favourably to lessen the impact of crisis. Thus, for example, both Germany and the Czech Republic (*i.e.*, both industry intensive) enter the crisis with lags of three and five months respectively from their respective nation groups. They also had a relative less severe crisis experience than, for example, finance-oriented Luxembourg and debt-ridden Greece. Eurozone members are confirmed to have been more adversely hit by the global financial crisis.

[Table 8 here]

5.4 Conceptual and Empirical Issues

When a period of economic growth comes to an abrupt end, economic policy becomes focused upon moderating the severity of the ensuing downturn. The recession that is experienced across nations may be differentially exacerbated by the extent of contagion, which is by no means homogeneous as evidenced by the measures we deployed in previous sections of this paper. That broad term, contagion, encompasses a variety of inter-related causes and consequences. These include the collapse of a speculative "bubble", the negative income multiplier, de-leveraging of bank credit, profit-taking (or damage limitation) in equity markets, a downgrade of credit ratings, rising debt-to GDP ratios and sovereign debt restructuring. Moreover, in applying remedial policy measures, sovereign treasuries and their companion central banks will have different strengths and their respective interventions will be conducted with varying degrees of understanding and expertise. The single euro currency *per se* may have hindered efficient market adjustments. Where, within the US and the UK, there are inter-regional permanent fiscal transfers these are non-existent within the Eurozone.[28] The cliché is that one size must fit all; which means that although the ECB might deliver a general level of Eurozone prices that is stable, unique structural changes within national economies may require "internal revaluations"; *i.e.*, individual price and wage realignments. Our analysis engages with that complex detail only with the broadest of brush-strokes, but the relevance upon the crisis experience in the PIIGS is apparent.

In Greece, social welfare and pensions were not funded by tax, so euros were paid out on the basis of a growing sovereign debt at the expense of labour and pension reforms that may have increased the competitiveness of the Greek economy.[29] Euros were used to finance import expenditures and this showed up as increasing Target 2 imbalances for the Bank of Greece. Similar practices were typical of the other PIIGS nations to a varying extent. In parallel, the ECB's posture that all Eurozone-wide sovereign debt bears virtually no risk (as evidenced by its stance on risk capital regulation and as liquidity provider, see Castellacci and Choi, 2005) allowed market participants to presume that cross-border liabilities would be guaranteed, either via government intervention and international bail-out programmes; or indeed that risk differentials had been factored out completely (Sbracia and Zaghini, 2001). Consequently, financial institutions increased their exposure to the PIIGS, while the ability to contain potential contagious damage was decreasing (Castellacci and Choi, 2015). It is in the nature of markets that the refinancing difficulties of a single nation cause participants to re-evaluate their perceptions of other nations, and their reactions are the drivers of contagion (Bekaert *et al.*, 2011; Missio and Watzka, 2011). To the sensitivity of market participants' reactions, catalytic was the role of the Lehman collapse (September 2008) that, economic consequences aside, raptured the belief that one of the largest, triple-AAA accredited financial institutions cannot go bust.

In the EU, the game was set and in 2009 the newly elected Greek government revised upwards the budget deficit to 12.7%, over four times higher than the maximum allowed for Eurozone members, while the

[28] The European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM), two institutions that would allow the transfer of funds between EU nations for the short and long-term stability respectively came into force in 2013.

[29] Eventually such reforms were imposed through a number of austerity packages by the EU, the European Central Bank (ECB) and the International Monetary Fund (IMF) (commonly referred to as Troika). Kosmidou et al. (2015) provide a nice exposition of the Greek crisis.

European Commission condemns Greece for falsifying its statistics[30] (*i.e.*, Greek statistics scandal). Market nervousness unveiled amidst these developments with Greece losing the A-grade in credit ratings. By late, 2010 markets realised that fiscal conditions in the PIIGS were much more precarious than had been expected and further credit score downgrades ensued. Other of the PIIGS would follow suit as markets began to speculate on the next weakest link.

As market participants unwounded their positions, they facilitated the contagion spread process. This is particularly evident in the case of the NMS. Relatedly, Arvai *et al.*, (2009) report that in most of the NMS, Austrian, Belgian, German and Italian financial institutions commanded the majority of the banking assets. While the expansion of credit to the private sector was aiding growth, financial stability was undermined (Cottarelli et al., 2003). NMS nations that were dependent on a single lender were affected later but at a higher intensity compared to countries with more diversified sources of funds (Árvai *et al.*, 2009). This may be a plausible explanation for countries (*e.g.*, Estonia, Hungary) that entered the crisis later and at a high crisis intensity score.

6. Conclusion

This paper investigates the impact of the global financial crisis on EU stock markets using an ADCC-GARCH model with a Markov switching component. Using data for the period 2001 to 2011, the work seeks to establish when each of Europe's stock markets entered a crisis regime, how long each market remained in that regime and how severe was the crisis. The current EU Member States are a diverse group with very different equity markets. For example, the markets in the countries that acceded in the last decade are much less developed, both in terms of size and activity, than those in the EU-15. It is therefore pertinent to question whether markets in the two blocs of countries display symmetric responses to such a shock as the global financial crisis. Of particular interest is any evidence of a spread in the pattern of the effects across the EU stock markets. Such evidence would indicate contagion and provide some indication of the degree of equity market integration in Europe.

The results presented in the paper uphold the presence of contagion. In broad terms and as expected, markets in the EU-15 were affected earlier than those in the NMS, a finding which reflects the greater exposure of the older members to world markets. Moreover, the EU-15 experienced shaper falls in financial markets than the NMS, and they also recovered more slowly. Even within the EU-15 nations, differences did emerge where, not surprisingly, the PIIGS countries were most affected by the crisis. The NMS that were frontrunners in the accession process were also hit by the crisis earlier than those that entered into membership negotiations later. Differences also emerged regarding both the severity and the duration of the crisis in these nations. The work also revealed that the nature of the relationships between EU stock markets changed in the aftermath of the crisis with markets in Scandinavia, the PIIGS countries and the leading NMS economies becoming more closely aligned.

While many factors doubtless contribute to explain why EU stock markets displayed differing reactions to the crisis, attention here focussed on a number of key macroeconomic indicators. Results from a simple

[30] The well-known scandal with Greece manipulating its financials (widely known as "Greek statistics") led to substantial reforms at the EU level whereby EU governments will have to sign written pledges that they will not make political appointments in the sector and on the independence of national number-grinders more broadly (Pop, 2012).

regression exercise revealed that both a high degree of industrialisation and a low level of government debt served to lessen the impact of the crisis. From a policy perspective, this suggests two lessons. First, it reinforces the EU's desire for Member States to maintain a sound fiscal policy, as detailed in the Stability and Growth Pact. Second, it might make governments in the NMS in particular think twice about allowing manufacturing to decline as the growth of services has been favoured, which has been the case in certain EU-15 nations.

References

Acharya, V., and Pedersen, L. (2005) 'Asset pricing with liquidity risk'. Journal of Financial Economics 77: 375-410.

Aielli, G. P. (2013) 'Dynamic Conditional Correlation: On Properties and Estimation', *Journal of Business & Economic Statistics,* 31(3), 282-299.

Árvai, Z., Driessen, K. and Otker-Robe, I. (2009) 'Regional Financial Interlinkages and Financial Contagion within Europe', *Finance a Uver-Czech Journal of Economics and Finance,* 59(6), 522-540.

Asgharian, H. and Nossman, M. (2011) 'Risk contagion among international stock markets', *Journal of International Money and Finance,* 30(1), 22-38.

Augustyniak, M. (2014) 'Maximum likelihood estimation of the Markov-switching GARCH model', *Computational Statistics & Data Analysis,* 76, 61-75.

Baele, L. (2005) 'Volatility spillover effects in European equity markets', *Journal of Financial and Quantitative Analysis,* 40(2), 373-401.

Baele, L. and Inghelbrecht, K. (2009) 'Time-varying Integration and International diversification strategies', *Journal of Empirical Finance,* 16(3), 368-387.

Baele, L. and Inghelbrecht, K. (2010) 'Time-varying integration, interdependence and contagion', *Journal of International Money and Finance,* 29(5), 791-818.

Baig, T. and Goldfajn, I. (1999) 'Financial market contagion in the Asian crisis', *International Monetary Fund Staff Papers*, 46(2), 167-195.

Baur, D.G. (2012). Financial contagion and the real economy. Journal of Banking and Finance, 36, 2680–2698.

Bauwens, L., Dufays, A. and Rombouts, J. V. K. (2014) 'Marginal likelihood for Markov-switching and change-point GARCH models', *Journal of Econometrics*, 178, 508-522.

Bauwens, L., Preminger, A. and Rombouts, J. V. K. (2010) 'Theory and inference for a Markov switching GARCH model', *Econometrics Journal,* 13(2), 218-244.

Bekaert, G., Ehrmann, M., Fratzscher, M. and Mehl, A. (2014) 'The Global Crisis and Equity Market Contagion', *Journal of Finance*, 69(6), 2597-2649.

Bekaert, G., Harvey, C. R., Lundblad, C. T. and Siegel, S. (2013) 'The European Union, the Euro, and equity market integration', *Journal of Financial Economics,* 109(3), 583-603.

Bekaert, G., Harvey, C. R. and Ng, A. (2005) 'Market integration and contagion', *Journal of Business*, 78(1), 39-69.

Bekaert, G., Hodrick, R. J. and Zhang, X. Y. (2009) 'International Stock Return Comovements', *Journal of Finance,* 64(6), 2591-2626.

Billio, M. and Caporin, M. (2005) 'Multivariate Markov switching dynamic conditional correlation GARCH representations for contagion analysis', *Statistical Methods & Applications,* 14, 145-161.

BIS (2009). The international financial crisis: Timeline, impact and policy responses in Asia and the Pacific. Bank for International Settlements.

Blatt, D., Candelon, B. and Manner, H. (2014) 'Detecting financial contagion in a multivariate system', *Working Paper*.

Bley, J. (2009) 'European Stock market integration: fact or fiction?', *Journal of International Financial Markets Institutions & Money,* 19, 759-776.

Bollerslev, T., Marrone, J., Xu, L., and Zhou, H. (2014). Stock Return Predictability and Variance Risk Premia: Statistical Inference and International Evidence. Journal of Financial and Quantitative Analysis, 49(3), 663-661

Brunnermeier, M., and Pedersen, L. 2009. Predatory trading. Journal of Finance 60: 1825-1863.

Burns, P., Engle, R., Mezrich, J., 1998. Correlations and volatilities of asynchronous data. Journal of Derivatives 5, 7–18.

Calvo, G. A. (1998) *Capital Market Contagion and Recession: An Explanation of the Russian Virus,* University of Maryland: College Park, Maryland.

Calvo, G. A., Leiderman, L. and Reinhart, C. M. (1996) 'Inflows of capital to developing countries in the 1990s', *Journal of Economic Perspectives,* 10(2), 123-139.

Camacho, M., Perez-Quiros, G. and Saiz, L. (2008) 'Do European business cycles look like one?', *Journal of Economic Dynamics & Control,* 32(7), 2165-2190.

Caporin, M. and McAleer, M. (2014) 'Robust ranking of multivariate GARCH models by problem dimension', *Computational Statistics & Data Analysis,* 76, 172-185.

Cappiello, L., Engle, R. F. and Sheppard, K. (2006) 'Asymmetric Dynamics in the correlations of Global Bond and Equity Returns', *Journal of Financial Econometrics,* 4(4), 537-572.

Castellacci, G., and Choi, Y. (2015) Modeling contagion in the Eurozone crisis via dynamical systems. Journal of Banking and Finance, 50, 400-410.

Cerda, A. R. (2009) 'The Impact of government spending on the duration and intensity of Economic Crises: Latin America 1990-2000', *Working Paper*.

Charlemagne (2010, May 4) 'Why is it grim up north?', *The Economist,* Available online at: http://www.economist.com/blogs/charlemagne/2010/05/north_v_south

Chiang, T. C., Jeon, B. N. and Li, H. M. (2007) 'Dynamic correlation analysis of financial contagion: Evidence from Asian markets', *Journal of International Money and Finance,* 26(7), 1206-1228.

Chmielewska, A. (2010) 'Volatility and contagion between the CEE and Eurozone debt and equity markets – multivariate GARCH approach'. Warsaw School of Economics (mimeo).

Cho, J. H. and Parhizgari, A. M. (2008) 'East Asian financial contagion under DCC-GARCH', *International Journal of Banking and Finance*, 6(1).

Claessens, S., Lee, R. and Zechner, J. (2003) 'The Future of Stock Exchanges in European Union Accession Countries', *Corporation of London*.

Clayes, P. and Vasicek, B. (2014) 'Measuring bilateral spillover and testing contagion on sovereign bond markets in Europe', *Journal of Banking and Finance,* 46, 151-165.

Cottarelli, C., Dell'Ariccia, G. and Vladkova-Hollar, I. (2005) 'Early birds, late risers, and sleeping beauties: Bank credit growth to the private sector in Central and Eastern Europe and in the Balkans', *Journal of Banking & Finance*, 29(1), 83-104.

Coudert, V. and Gex, M. (2010) 'Contagion inside the credit default swaps market: The case of the GM and Ford crisis in 2005', *Journal of International Financial Markets, Institutions and Money*, 20(2), 109-134.

Dimitriou, D., Kenourgios, D., & Simos, T. (2013). Global financial crisis and emerging stock market contagion: A multivariate FIAPARCH-DCC approach. International Review of Financial Analysis, 30, 46–56.

ECB (2010) *EU Financial Integration Report*, Available online at: http://www.ecb.europa.eu/pub/pdf/other/financialintegrationineurope201004en.pdf.

ECB (2011) *EU Financial Integration Report*, Available online at: http://www.ecb.europa.eu/pub/pdf/other/financialintegrationineurope201105en.pdf.

Edwards, S. and Susmel, R. (2003) 'Interest-rate volatility in emerging markets', *Review of Economics and Statistics*, 85(2), 328-348.

Eichengreen, B. and Rose, A. K. (1999) 'Contagious currency crises: Channels of conveyance', *Changes in Exchange Rates in Rapidly Developing Countries*, 7, 29-55.

Engle, R. (2002) 'Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models', *Journal of Business & Economic Statistics*, 20(3), 339-350.

Engle, R. F. and Kroner, K. F. (1995) 'Multivariate Simultaneous Generalized Arch', *Econometric Theory*, 11(1), 122-150.

Estonia, M. o. F. o. t. R. o. (2013) *Review of the Estonian Financial System*. Available online at: http://www.eestipank.ee/en/publication/financial-stability-review/2013/financial-stability-review-22013

Pop, V. (2012, April 12) EU on Greek statistics scandal: “Never again”, Article on EU Observer, Available online at: https://euobserver.com/economic/115912

Eurobarometer (2013) 'Public Opinion in the European Union'. Available online at: http://naftemporiki.gr.s3.amazonaws.com/docs/2012/12/20/eb78.pdf

Fama, E. F. (1965) 'The Behavior of Stock-Market Prices', Journal of Business, 38(1), 34-105.

Federal Reserve Board of St. Louis (2009). The financial crisis: A timeline of events and policy actions.

Filardo, A. J. (1994) 'Business-Cycle Phases and Their Transitional Dynamics', *Journal of Business & Economic Statistics*, 12(3), 299-308.

Forbes, A. (2001) 'Contagion: How to Measure it?', *NBER Working Papers 8118*.

Forbes, K. J. and Rigobon, R. (2002) 'No contagion, only interdependence: Measuring stock market comovements', *Journal of Finance*, 57(5), 2223-2261.

Francq, C. and Zakoian, J. M. (2008) 'Deriving the autocovariances of powers of Markov-switching GARCH models, with applications to statistical inference', *Computational Statistics & Data Analysis*, 52(6), 3027-3046.

Gębka, B. and Karoglou, M. (2013) 'Have the GIPSI settled down? Breaks and multivariate stochastic volatility models for, and not against, the European financial integration', *Journal of Banking & Finance*, 37(9), 3639-3653.

Gelos, R. G. and Sahay, R. (2001) 'Financial market spillovers in transition economies', *Economics of Transition*, 9(1), 53-86.

Gjika, D. and Horváth, R. (2013) 'Stock market comovements in Central Europe: Evidence from the asymmetric DCC model', *Economic Modelling*, 33, 55-64.

Glynn, P. W. and Haas, P. J. (2004) 'On functional central limit theorems for semi-Markov and related processes', *Communications in Statistics-Theory and Methods*, 33(3), 487-506.

Gray, S. F. (1996) 'Modeling the conditional distribution of interest rates as a regime-switching process', *Journal of Financial Economics*, 42(1), 27-62.

Hamao, Y., Masulis, R. W. and Ng, V. (1990) 'Correlations in Price Changes and Volatility across International Stock Markets', *Review of Financial Studies*, 3(2), 281-307.

Hamilton, D. (1994) *Time Series Analysis*, Princeton: Princeton University Press.

Hardouvelis, G. A., Malliaropulos, D. and Priestley, R. (2006) 'EMU and European stock market integration', *Journal of Business*, 79(1), 365-392.

Hon, T. M., Strauss, J. and Yong, S.-K. (2004) 'Contagion in financial markets after September 11: Myth or Reality?', *Journal of Financial Research*, 27(1), 95-114.

Hwang, I., Haeuck In, F. and T.S., K. (2010) 'Contagion effect of the US subprime crisis on international stock markets'.

Jondeau, E., Rockinger, M., 2006. The copula-garch model of conditional dependencies: an international stock market application. Journal of International Money and Finance 25, 827–853.

Kalbaska, A., and Gatkowski, M. (2012). Eurozone sovereign contagion: Evidence from the CDS market (2005–2010). Journal of Economic Behavior and Organization, 83, 657–673.

Kahya, E., 1997. Correlation of returns in non-contemporaneous markets. Multinational Finance Journal 1, 123–135.

Kasch-Haroutounian, M. and Price, S. (2001) 'Volatility in the transition markets of Central Europe', *Applied Financial Economics*, 11, 93-105.

Kenourgios, D. (2014) On financial contagion and implied market volatility. International Review of Financial Analysis, 34, 21-30

Kenourgios, D., and Dimitriou, D. (2015) Contagion of the Global Financial Crisis and the real economy: A regional analysis. Economic Modelling, 44, 283-293.

Kenourgios, D., and Padhi, P., 2012. Emerging markets and financial crises: regional, global or isolated shocks? Journal of Multinational Financial Management, 22 (1–2), 24–38.

Kenourgios, D., Samitas, A., & Paltalidis, N. (2011). Financial crises and stock market contagion in a multivariate time-varying asymmetric framework. Journal of International Financial Markets Institutions and Money, 21, 92–106.

Khalid, A. and Rajaguru, G. (2007) 'Financial Market Contagion: Evidence from the Asian Crisis using a Multivariate GARCH Approach', *GDC Wworking Paper, Bond University*.

Kim, S. J., Moshirian, F. and Wu, E. (2005) 'Dynamic stock market integration driven by the European Monetary Union: An empirical analysis', *Journal of Banking & Finance,* 29(10), 2475-2502.

King, M. A. and Wadhwani, S. (1990) 'Transmission of Volatility between Stock Markets', *Review of Financial Studies,* 3(1), 5-35.

Klaassen, F. (2002) 'Improving GARCH volatility forecasts with regime-switching GARCH', *Empirical Economics,* 27(2), 363-394.

Kosmidou, K. V., Kousenidis, D. V., and Negakis, C. I. (2015) The impact of the EU/ECB/IMF bailout programs on the financial and real sectors of the ASE during the Greek sovereign crisis. Journal of Banking and Finance, 50, 440-454.

KPMG (2011) *Structuring Hedge Funds in Luxembourg*.

Kyle, S. A. and Xiong, W. (2001) Contagion as a Wealth Effect, The Journal of Finance, 56(4), 1401-1440

Ludwig, A. (2014) A unified approach to investigate pure and wake-up-call contagion: Evidence from the Eurozone's first financial crisis. Journal of International Money and Finance, 48, 125-146

Mandilaras, A. and Bird, G. (2010) 'A Markov switching analysis of contagion in the EMS', *Journal of International Money and Finance,* 29(6), 1062-1075.

Marcucci, J. (2005) 'Forecasting stock market volatility with regime-switching GARCH models', *Studies in Nonlinear Dynamics and Econometrics,* 9(4).

Masson, P. (1999) 'Contagion: macroeconomic models with multiple equilibria', *Journal of International Money and Finance,* 18(4), 587-602.

Martens, M., Poon, S., 2001. Returns synchronization and daily correlation dynamics between international stock markets. Journal of Banking and Finance 25, 1805–1827.

Naoui, K., Khemiri, S. and Liouane, N. (2010) 'Crises and Financial Contagion: The Subprime Crisis', *Journal of Business Studies Quarterly,* 2(1), 15-28.

Olbrys, J. and Majewska, E. (2014) 'Direct Identification of Crisis Periods on the CEE Stock Markets: The Influence of the 2007 US Subprime Crisis', *International Conference on Applied Economics (Icoae 2014),* 14, 461-470.

Pelletier, D. (2006) 'Regime switching for dynamic correlations', *Journal of Econometrics,* 131(1-2), 445-473.

Pericoll, M., and Sbracia, M., (2003) A Primer on Financial Contagion. Journal of Economic Surveys, 17(4), 571-608.

PwC (2008) *Luxembourg Hedge Funds*.

Savva, C. S. (2009) 'International Stock Market interactions and conditional correlations', *Journal of International Financial Markets Institutions & Money,* 19, 645-661.

Savva, C. S. and Aslanidis, N. (2010) 'Stock market integration between new EU member states and the Euro-zone', *Empirical Economics,* 39(2), 337-351.

Sbracia, M. and Zaghini, A. (2003) 'The role of the banking system in the international transmission of shocks', *World Economy,* 26(5), 727-754.

Scheicher, M. (2001) 'The comovements of stock markets in Hungary, Poland and the Czech Republic', *International Journal of Finance & Economics,* 6(1), 27-39.

Serwa, D. and Bohl, M. (2005) 'Financial contagion vulnerability and resistance: A comparison of European stock markets', *Economic Systems,* 29, 344-362.

Silvennoinen, A. and Teräsvirta, T. (2008) 'Multivariate GARCH models' in Andersen, T. G., Davis, R. A., Kreiss, J.-P. and Mikosch, T., eds., *Handbook of Financial Time Series*, New York: Springer.

Suh, S. (2015) Measuring sovereign risk contagion in the Eurozone. International Review of Economics and Finance, 35, 45-65

Syllignakis, M. N. and Kouretas, G. P. (2011) 'Dynamic correlation analysis of financial contagion: Evidence from the Central and Eastern European markets', *International Review of Economics & Finance,* 20(4), 717-732.

Teräsvirta, T. (1994) 'Specification, Estimation, and Evaluation of Smooth Transition Autoregressive Models', *Journal of the American Statistical Association*, 89(425), 208-218.

Tong, H. (2005) *Nonlinear Time Series Analysis*, *Encyclopedia of Biostatistics.* , John Wiley & Sons, Ltd.

Tsay, R. S. (2010) 'Financial Time series and Their Characteristics, Multivariate Time Series Analysis and Its Application' in *Analysis of financial time series*, 3rd edition ed., New Jersey: Wiley, Hoboken.

Tse, Y. K. and Tsui, A. K. C. (2002) 'A multivariate generalized autoregressive conditional heteroscedasticity model with time-varying correlations', *Journal of Business & Economic Statistics,* 20(3), 351-362.

Wang, P. and Moore, T. (2008) 'Stock market integration for the transition economies: Time-varying conditional correlation approach', *Manchester School,* 76, 116-133.

Yang, J., Min, I. and Li, Q. (2003) 'European stock market integration: does EMU matter?', *Journal of Business Finance and Accounting,* 30, 1253-1276.

Yiu, M., Ho, W. and Choi, D. (2010) 'Dynamic correlation analysis of financial contagion in Asian markets in global financial turmoil', *Applied Financial Economics,* 20(4), 345-354.

Zivot, E. and Andrews, W. K. D., (1992) 'Further evidence on the Great Crash, the oil price shock, and the unit-root hypothesis', *Journal of Business & Economic Statistics*, 10 (3), pp. 251-70

Tables

Table 1. EU Indices, Symbols and Sources

	Nations	Index	Symbol	Source
		Scandinavian		
EU-15	Denmark	OMXC 20	DKKFXIN	Stockholmsborsen
	Finland	OMXH	HEXINDX	Stockholmsborsen
	Sweden	OMXC 30	SWEDOMX	Stockholmsborsen
		Core EU		
	Austria	ATX	ATXINDX	Wiener Boerse
	Belgium	BEL 20	BGBEL20	BEL
	France	CAC 40	FRCAC40	Euronext Paris
	Germany	DAX 30	DAXINDX	Deutsche Borse
	Luxembourg	SE General	LUXGENI	Luxembourg Stock Exchange
	Netherlands	AEX	AMSTEOE	Euronext Amsterdam
	UK	FTSE All Share	FTALLSH	United Kingdom Stock Exchange
		PIIGS		
	Portugal	PSI General	POPSIGN	Euronext Lisbon
	Italy	FTSE MIB	FTSEMIB	FTSE
	Ireland	SE Overall	ISEQUIT	Irish Stock Exchange
	Greece	ATHEX Composite	GRAGENL	Athens Stock Exchange
	Spain	IBEX 35	IBEX35	Spanish Exchanges
		Baltics		
New Member States (NMS)	Estonia	OMX Tallin	ESTALSE	Stockholmsborsen
	Latvia	OMX Riga	RIGSEIN	Stockholmsborsen
	Lithuania	OMX Vilnius	LNVILSE	Stockholmsborsen
		RAMS I		
	Czech Republic	SE PX	CZPXIDX	Prague Stock Exchange
	Hungary	BUX	BUXINDX	Budapest Stock Exchange
	Poland	Warsaw General Index	POLWIGI	Warsaw Stock Exchange
	Slovenia	DS Market	TOTXRSJ	Datastream
		RAMS II		
	Bulgaria	SE SOFIX	BSSOFIX	Bulgaria Stock Exchange
	Cyprus	FTSE Cyprus SE 20	FTSEC20	FTSE
	Malta	SE MSE	MALTAIX	Borza ta' Malta
	Romania	BET	RMBETRL	BET Indices
	Slovakia	SAX 16	SXSAX16	Bratislava Stock Exchange

Notes: All data downloaded from Datastream

Table 2. Macroeconomic Indicators

Nations	Population Millions	GDP Constant 2000 $bil	GDP Real Growth %	GDP/capita Constant 2005 $bil, PPP	*Industry* *% of GDP*	*CAB* *% of GDP*	*Debt* *% of GDP*	*Labour Cost* *%*	*REER*	Market Cap % of GDP
Scandinavian										
Denmark	5.54	171.23	2.09	32,608	40.06	3.80	41.30	71.90	100.18	74.66
Finland	5.36	145.56	-8.20	31,532	56.57	3.26	44.94	66.23	100.11	49.48
Sweden	9.38	1,698.16	1.25	33,686	47.52	8.38	47.21	68.84	98.62	126.89
Core EU										
Austria	8.38	222.63	1.96	35,266	49.65	2.85	67.92	69.06	99.10	17.99
Belgium	10.88	266.51	2.18	32,824	41.52	0.44	91.27	70.04	99.46	57.62
France	64.87	1,484.70	-2.73	29,647	34.63	-1.24	74.34	69.27	98.72	75.25
Germany	81.70	2,071.24	-4.72	33,498	51.74	6.12	44.76	68.88	99.06	43.20
Luxembourg	0.51	27.38	3.52	71,161	26.04	8.61	8.17	58.54	100.36	183.55
Netherlands	16.61	440.12	1.77	36,915	38.60	7.20	53.01	68.89	98.72	84.40
UK	62.22	302.11	2.92	32,187	37.76	-2.35	56.78	71.85	94.29	138.33
PIIGS										
Portugal	10.64	124.99	1.33	21,658	41.03	-10.36	74.46	68.44	99.47	35.88
Italy	60.48	1,125.08	1.30	26,753	46.14	-2.58	112.29	68.07	99.06	15.51
Ireland	4.48	123.81	-1.04	35,183	62.72	-2.59	49.25	56.17	100.02	16.54
Greece	11.32	158.67	-4.47	24,990	29.21	-11.42	125.68	67.00	100.74	23.83
Spain	46.08	712.34	-0.14	26,934	44.91	-6.99	44.56	65.11	100.36	83.25
Baltics										
Estonia	1.34	77.63	1.78	16,353	41.47	-5.99	6.07	63.14	n/a	12.10
Latvia	2.24	11.22	-0.34	12,938	34.86	-8.73	34.21	58.04	n/a	5.21
Lithuania	3.32	17.53	1.33	15,390	50.37	-6.16	27.96	56.30	n/a	15.59
RAMS I										
Czech Republic	10.52	19.21	2.32	22,557	63.34	-2.68	24.35	59.37	106.97	22.41
Hungary	10.01	57.01	1.17	16,514	47.20	-3.95	70.99	64.28	98.98	21.25
Poland	38.18	250.89	3.82	17,336	48.46	-4.72	37.17	58.43	101.42	40.60
Slovenia	2.05	26.00	1.18	24,982	53.32	-2.42	n/a	72.90	n/a	19.74
RAMS II										
Bulgaria	7.54	8.25	0.20	11,486	52.32	-12.76	14.74	54.40	107.40	15.25
Cyprus	1.10	12.17	-1.02	25,803	25.21	-8.80	145.22	62.22	99.89	19.94
Malta	0.41	4.43	-2.12	22,102	58.45	-5.86	80.28	n/a	99.72	24.81
Romania	21.44	56.53	0.95	10,929	53.88	-8.18	n/a	51.59	98.76	20.04
Slovakia	5.43	43.78	0.50	19,244	59.94	-4..35	39.19	50.75	108.72	4.66

Notes: Data are 2010, except when in italics which indicates data averaged over the 2001-2011 period. CAB is the Current Account Balance. REER is the Real Effective Exchange Rate.

Table 3. Descriptive Statistics of EU Stock Markets

Nations	Mean %	Volatility Annualised %	JB	VaR 95%	EMH Test
Scandinavian	**-0.0089**	**25.35**			
Denmark	0.0040	21.51	4,314***	-8.15	-1.079
Finland	-0.0280	28.87	3,695***	-11.27	-2.690***
Sweden	-0.0026	25.68	1,533***	-7.60	0.101
Core EU	**-0.0022**	**22.26**			
Austria	0.0230	24.14	7,717***	-9.33	-1.322
Belgium	-0.0122	21.58	4,556***	-7.51	-1.757*
France	-0.0226	24.88	3,278***	-8.20	1.188
Germany	0.0426	8.95	14,598***	-4.29	-7.997***
Luxembourg	-0.0151	30.76	3,422***	-16.46	-2.138**
Netherlands	-0.0287	25.65	4,027***	-8.99	-0.788
UK	-0.0021	19.87	4,482***	-7.56	-0.753
PIIGS	**-0.0246**	**23.08**			
Portugal	-0.0027	17.27	17,629***	-7.33	-4.430***
Italy	-0.0370	23.98	4,204***	-7.83	0.796
Ireland	-0.0287	24.19	6,747***	-10.62	-3.284***
Greece	-0.0517	25.77	3,432***	-8.36	-5.293***
Spain	-0.0027	24.21	4,631***	-8.37	0.651
Baltics	**0.0426**	**21.29**			
Estonia	0.0487	19.21	7,497***	-6.48	-7.371***
Latvia	0.0324	25.35	2,459***	-12.97	1.697*
Lithuania	0.0467	19.31	4,634***	-10.02	-5.964***
RAMS I	**0.0226**	**21.79**			
Czech Republic	0.0251	24.30	2,064***	-12.49	-1.399
Hungary	0.0261	26.13	4,927***	-10.59	0.011
Poland	0.0277	21.11	1,074***	-7.10	0.396
Slovenia	0.0115	15.60	1,084***	-7.17	-7.741***
RAMS II	**0.0158**	**24.29**			
Bulgaria	0.0424	27.71	9,527***	-16.69	-5.737***
Cyprus	-0.0667	34.76	2,264***	-10.79	-2.881***
Malta	-0.0026	12.07	7,630***	-4.51	-9.796***
Romania	0.0735	27.82	6,162***	-11.86	-5.864***
Slovakia	0.0324	19.09	4,577***	-10.86	-2.533**

Notes: EMH test is the z-statistic for the Runs test of the efficient market hypothesis. ***, **, * denote significance at the 1, 5, 10% significance levels respectively.

Table 4. Univariate Markov-Switching GARCH Models

		Calm ($s_t = 0$)				Crisis ($s_t = 1$)				Goodness-of-fit			Transition Probabilities	
		θ0	**ω0**	**α0**	**β0**	**θ1**	**ω1**	**α1**	**β1**	**AIC**	**BIC**	**LR Test**	**[0,0]**	**[1,1]**
Scan/an	Denmark	0.0126***	0.0005***	0.9992***	0.0000	0.0097***	0.0003***	0.8625***	0.0000	-10.0749	-10.0537	7716.50***	0.9792	0.9685
	Finland	0.0172***	0.0005***	1.0276***	0.0000	0.0099***	0.0002***	0.9700***	0.0471***	-9.2538	-9.2326	6491.40***	0.9946	0.9899
	Sweden	1.2665	1.2865	0.0000	0.0000	0.0125***	0.0005***	1.0577***	0.0000	-8.2689	-8.2477	4213.30***	0.8883	0.9996
Core EU	Austria	0.0154***	0.0008***	0.9788***	0.0000	0.0102***	0.0004***	0.8341***	0.0406	-9.8016	-9.7804	8618.80***	0.9835	0.9863
	Belgium	0.0140***	0.0009***	0.9848***	0.0000	0.0085***	0.0004***	0.8927***	0.0000	-9.6207	-9.5995	7117.90***	0.9881	0.9861
	France	0.0150***	0.0008***	0.9886***	0.0122	0.0094***	0.0004***	0.9778***	0.0000	-9.5107	-9.4895	7335.90***	0.9907	0.9873
	Germany	0.0161***	0.0009***	1.0023***	0.0050	0.0105***	0.0005***	0.9397***	0.0046	-9.3753	-9.3541	6870.60***	0.9896	0.9890
	Luxembourg	0.0172***	0.0019***	1.0230***	0.0000	0.0101***	0.0007***	0.9549***	0.0000	-8.4854	-8.4642	7245.00***	0.9748	0.9708
	Netherlands	0.0146***	0.0009***	0.9827***	0.0000	0.0091***	0.0004***	0.8514***	0.0437	-9.3481	-9.3269	7472.20***	0.9870	0.9839
	UK	0.0121***	0.0005***	1.0053***	0.0195	0.0079***	0.0003***	0.9497***	0.0000	-9.8138	-9.7926	7604.10***	0.9796	0.9785
PIIGS	Portugal	0.0130***	0.0008***	0.9518***	0.0000	0.0084***	0.0004***	0.9009***	0.0000	-9.9347	-9.9135	7379.80***	0.9870	0.9868
	Italy	0.0142***	0.0007***	1.0547***	0.0036	0.0090***	0.0004***	0.9478***	0.0138	-9.3457	-9.3245	7223.30***	0.9903	0.9873
	Ireland	0.0155***	0.0009***	0.9699***	0.0165	0.0092***	0.0003***	0.8582***	0.0870***	-9.6006	-9.5794	7631.80***	0.9816	0.9818
	Greece	0.0203***	0.0007***	1.0325***	0.0009	0.0108***	0.0003***	0.9950***	0.0153	-9.5309	-9.5097	7251.40***	0.9869	0.9900
	Spain	0.0157***	0.0007***	0.9941***	0.0006	0.0088***	0.0003***	0.9523***	0.0113	-9.5935	-9.5723	7497.50***	0.9876	0.9809
Baltics	Estonia	0.0137***	0.0006***	1.0384***	0.0000	0.0096***	0.0004***	0.8737***	0.0740***	-9.9139	-9.8927	6367.00***	0.9796	0.9804
	Latvia	0.0165***	0.0011***	0.9433***	0.0000	0.0105***	0.0005***	0.9288***	0.0000	-9.6356	-9.6144	8111.60***	0.9555	0.9684
	Lithuania	0.0117***	0.0006***	0.8749***	0.0051	0.0090***	0.0003***	1.1777***	0.0000	-10.0327	-10.0115	7417.10***	0.9672	0.9389
RAMS I	Czech R'blic	0.0156***	0.0008***	0.9358***	0.0000	0.0110***	0.0005***	0.9502***	0.0000	-9.6168	-9.5956	8207.10***	0.9706	0.9697
	Hungary	0.0196***	0.0010***	0.9833***	0.0157	0.0138***	0.0005***	0.8771***	0.0000	-9.2964	-9.2751	7542.60***	0.9740	0.9772
	Poland	0.0192***	0.0008***	1.0119***	0.0022	0.0136***	0.0005***	0.9221***	0.0000	-9.6757	-9.6545	6786.10***	0.9777	0.9900
	Slovenia	0.8314***	0.0712***	0.9710***	0.0000	0.0095***	0.0004***	0.8632***	0.0000	-10.1958	-10.1789	6047.20***	0.9796	1.0000
RAMS II	Bulgaria	0.0173***	0.0011***	1.0251***	0.0000	0.0100***	0.0006***	0.9911***	0.0000	-8.9367	-8.9155	7293.10***	0.9739	0.9743
	Cyprus	0.0219***	0.0013***	0.9831***	0.0025	0.0128***	0.0006***	1.0037***	0.0000	-8.4467	-8.4255	5787.50***	0.9796	0.9658
	Malta	0.0102***	0.0004***	1.0464***	0.0000	0.0081***	0.0002***	0.8953***	0.0000	-11.2463	-11.2251	5180.60***	0.9714	0.9794
	Romania	0.0190***	0.0009***	0.9860***	0.0000	0.0133***	0.0006***	0.9768***	0.0000	-9.0523	-9.0310	6753.10***	0.9778	0.9787
	Slovakia	0.0140***	0.0001***	1.0436***	0.0000	0.0120***	0.0001***	1.0283***	0.0000	-10.4816	-10.4604	5915.30***	0.9880	0.9854

Notes: The table reports coefficients and goodness-of-fit statistics for the univariate Markov-Switching GARCH models fitted on each of the 27 nations of our sample. Estimation period is $1/1/2001 - 27/9/2011$ ($T = 2800$). The model estimated for every nation is given by: $r_t = \theta_{s_t} + u_t, u_t \sim iid(0, h_{t,s_t}); h^2_{t,s_t} = \omega_{s_t} + a_{s_t} u^2_{t-1} + \beta_{s_t} h^2_{t-1}; s_t = \{0,1\}$. AIC and BIC denote the Akaike and Bayesian Information Criteria respectively. The LR column reports the chi-square statistics for the linearity test. Columns [0,0] and [1,1] denote the transition probabilities for the volatility process staying in the calm and crisis regime respectively over two consecutive time periods. ***, **, * denote significance at the 1, 5, 10% significance levels respectively.

Table 5: Multivariate Conditional Correlation Models Estimation Results.

	DCC(1,1)		**ADCC(1,1,1)**	
	Coefficient	Standard Error	Coefficient	Standard Error
a	0.0053***	0.0003	0.0049***	0.0003
b	0.9910***	0.0007	0.9909***	0.0008
g	—	—	0.0025***	0.0005
AIC	-179.12		-179.36	
BIC	-179.11		-179.35	
LogL	318,380.74		318,813.47	
LR Test	—		865.46***	
T	2,800		2,800	
N	27		27	

Notes: The table reports coefficients, standard errors and goodness of fit statistics for the multivariate DCC-GARCH and ADCC-GARCH models fitted on the sample. AIC and BIC denote the Akaike and Bayesian Information Criteria respectively while LogL denotes the log likelihood. LR Test is the likelihood ratio test between the DCC-GARCH and ADCC-GARCH models. A rejection of the null hypothesis indicates that the ADCC-GARCH is a significant improvement over the DCC-GARCH. ***, **, *: denote significance at the 1, 5, 10% significance levels respectively.

Table 6: Crisis Transition Dates, Synchronization, Duration and Intensity measures

	I Nation	II Crisis Transition Date	III Sync *(Days)*	IV Duration *(Days)*	V Duration *(%)*	VI Intensity *(%)*	VII Credit Score Change pre	VIII post	IX Credit Score Lead/Lag pre	X post
Scan/an	Denmark	10/08/2007	9	940	95.43	56.70	—	—	—	—
	Finland	13/08/2007	12	831	80.92	52.62	—	—	—	—
	Sweden	27/07/2007	-5	631	61.62	62.94	—	—	—	—
	Scandinavian		**9**	**831**	**80.92**	**56.70**			**—**	**—**
Core EU	Austria	27/07/2007	-5	956	93.54	67.10	—	—	—	—
	Belgium	26/07/2007	-6	930	92.08	73.55	02/05/2006	23/05/2011	450	1,397
	France	09/08/2007	8	905	92.07	66.92	—	—	—	—
	Germany	06/11/2007	97	677	75.73	71.97	—	—	—	—
	Luxembourg	01/03/2007	-153	972	92.40	73.75	—	—	—	—
	Netherlands	10/08/2007	9	880	88.71	71.61	—	—	—	—
	UK	26/07/2007	-6	932	95.20	61.21	—	14/03/2012	—	1,693
	Core EU		**-5**	**930**	**92.08**	**71.61**			**450 (1.23)**	**1,545 (4.23)**
PIIGS	Portugal	10/08/2007	9	915	91.50	64.50	01/05/2007	03/09/2009	101	755
	Italy	10/08/2007	9	969	93.71	75.73	19/10/2006	07/10/2011	295	1519
	Greece	16/01/2008	168	873	97.43	60.03	05/03/2007	20/10/2008	317	278
	Ireland	27/07/2007	-5	888	84.98	73.68	21/09/2000	06/03/2009	2,500	588
	Spain	02/08/2007	1	910	91.73	69.84	10/12/2003	28/05/2010	1,331	1,030
	PIIGS		**9**	**910**	**91.73**	**69.84**			**317 (0.87)**	**755 (2.07)**
Baltics	Estonia	21/07/2008	355	653	91.71	58.89	31/01/2008	03/10/2008	172	74
	Latvia	16/09/2008	412	573	86.04	47.67	31/01/2008	03/10/2008	229	17
	Lithuania	09/09/2008	405	550	94.83	23.82	07/12/2007	03/10/2008	277	24
	Baltics		**405**	**573**	**91.71**	**47.67**			**229 (0.63)**	**24 (0.07)**
RAMS I	Czech	09/01/2008	161	631	84.81	56.62	26/08/2005	04/03/2008	866	55
	Hungary	28/11/2007	119	785	87.32	72.43	05/11/2007	15/10/2008	23	322
	Poland	06/08/2007	5	584	61.47	60.37	18/01/2007	—	200	—
	Slovenia	04/01/2007	-209	480	41.45	59.05	12/07/2006	28/09/2011	176	1728
	RAMS I		**62**	**608**	**73.14**	**59.71**			**188 (0.52)**	**322 (0.88)**
RAMS II	Bulgaria	12/11/2007	103	525	61.98	70.49	17/08/2005	30/01/2008	817	79
	Cyprus	17/01/2008	169	873	99.32	16.52	12/07/2007	31/05/2011	189	1230
	Malta	29/07/2008	363	448	67.57	35.76	12/07/2007	—	383	—
	Romania	07/01/2008	159	636	75.27	70.46	31/08/2006	31/01/2008	494	24
	Slovakia	18/09/2008	414	640	88.03	36.46	08/07/2008	—	72	—
	RAMS II		**169**	**636**	**71.42**	**53.46**			**383 (1.05)**	**79 (0.22)**
	EU-15		**8**	**910**	**92.07**	**67.10**			**384 (1.05)**	**1,030 (2.82)**
	NMS		**165*****	**608*****	**85.43***	**57.76*****			**215 (0.59)**	**74 (0.20)**

Notes: Crisis Transition Date (CTD) is identified by the MS-GARCH model. Credit Score Change (CSC) refers to sovereign credit score change date pre and post the CTD in every nation. Credit score ratings are provided by Fitch ratings. Credit Score Lead/Lag refers to the difference, expressed in days (years), between the Credit Score Change and the Crisis Transition Date. Credit rating scores provided by Fitch ratings. Numbers in bold represent nation group median values. ***, **, * denote statistical significance levels at the 1%, 5% and 10% respectively for the Mann-Whitney test for the equality of medians.

Table 7. EU-wide and intra-EU correlation measures

I	II	III	IV	V	VI	VII
Nation Groups	**Average Correlations**		**Change in Correlations**			
	Pre-crisis	**Post-crisis**	**Median**	**Mean**	**SD**	**p-value**
			Panel A			
Scandinavian	44.12%	45.79%	4.05%	3.80%	0.53%	0.000***
Core EU	39.08%	40.51%	3.92%	4.03%	0.82%	0.000***
PIIGS	43.04%	44.60%	4.32%	3.70%	0.76%	0.000***
Baltics	18.44%	19.87%	9.77%	8.27%	3.39%	0.081*
RAMS I	21.69%	22.70%	5.05%	4.43%	3.65%	0.021**
RAMS II	24.76%	26.30%	7.94%	-2.64%	14.84%	0.667
			Panel B			
Scandinavian	68.80%	70.50%	2.62%	2.55%	0.87%	0.015**
Core EU	49.26%	51.00%	4.83%	5.20%	4.45%	0.017**
PIIGS	59.35%	60.54%	3.38%	3.25%	6.57%	0.207
Baltics	26.83%	28.63%	7.00%	6.38%	1.42%	0.004***
RAMS I	36.48%	38.53%	6.33%	6.15%	2.43%	0.007***
RAMS II	4.72%	5.25%	10.32%	-24.58%	78.84%	0.517

Notes: The table reports the EU-wide (Panel A) and intra-EU (Panel B) average conditional correlation coefficients from the ADCC model pre and post-crisis for every nation group. The cut-off date separating the pre- and post-crisis periods is the crisis transition date for each country (see Table 5). The change in the correlation measures refers to the change between the pre- and post-crisis periods.

Table 8. Correlation Analysis

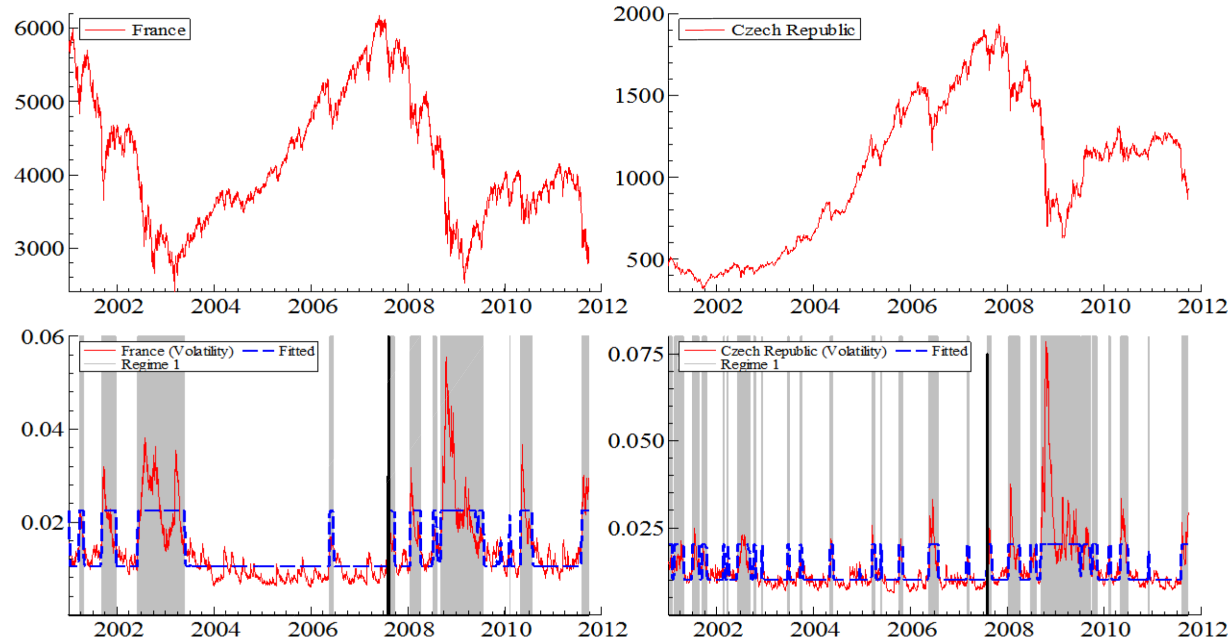
	UCP
Current Account Balance	0.416*
Central Government Debt	0.093
Unit Labour Cost	0.144
REER	0.414*
Industrialisation	-0.399*
Eurozone	0.691***

Notes: Table reports estimated Spearman rank-order correlation coefficients. Current Account Balance, Central Government Debt and Industrialisation are measured as percentage of GDP. REER is the Real Effective Exchange Rate. UCP is the Unified Crisis Performance. *, **, ***: 10%, 5% and 1% statistical significance respectively.

Figure 1. Index Prices and Regime identification

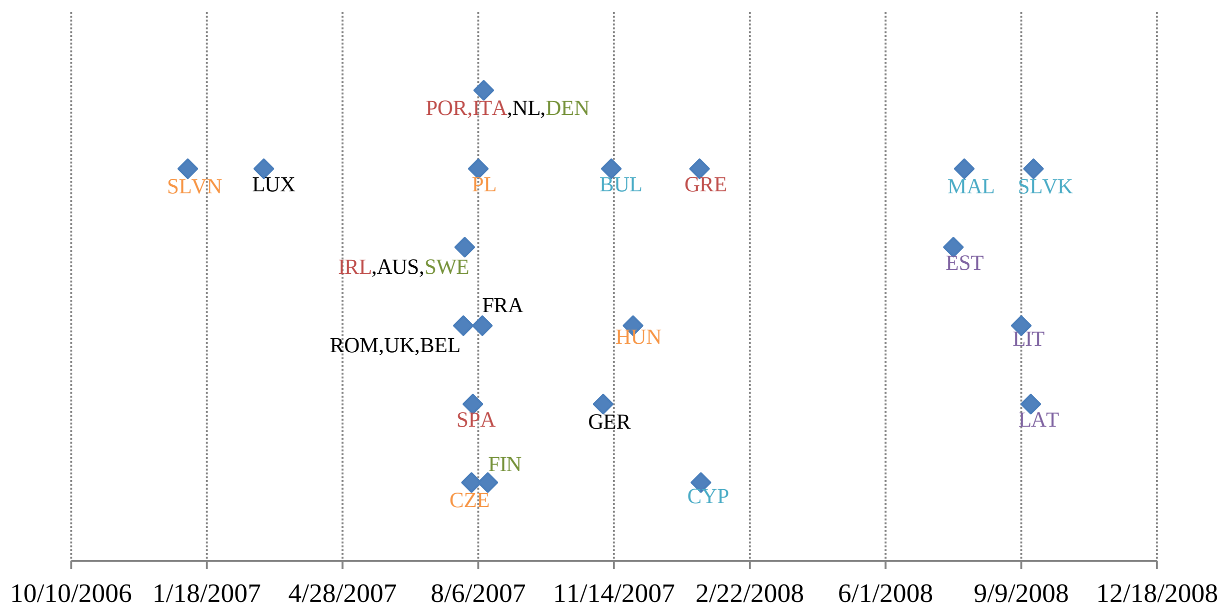
Panel A

Panel B



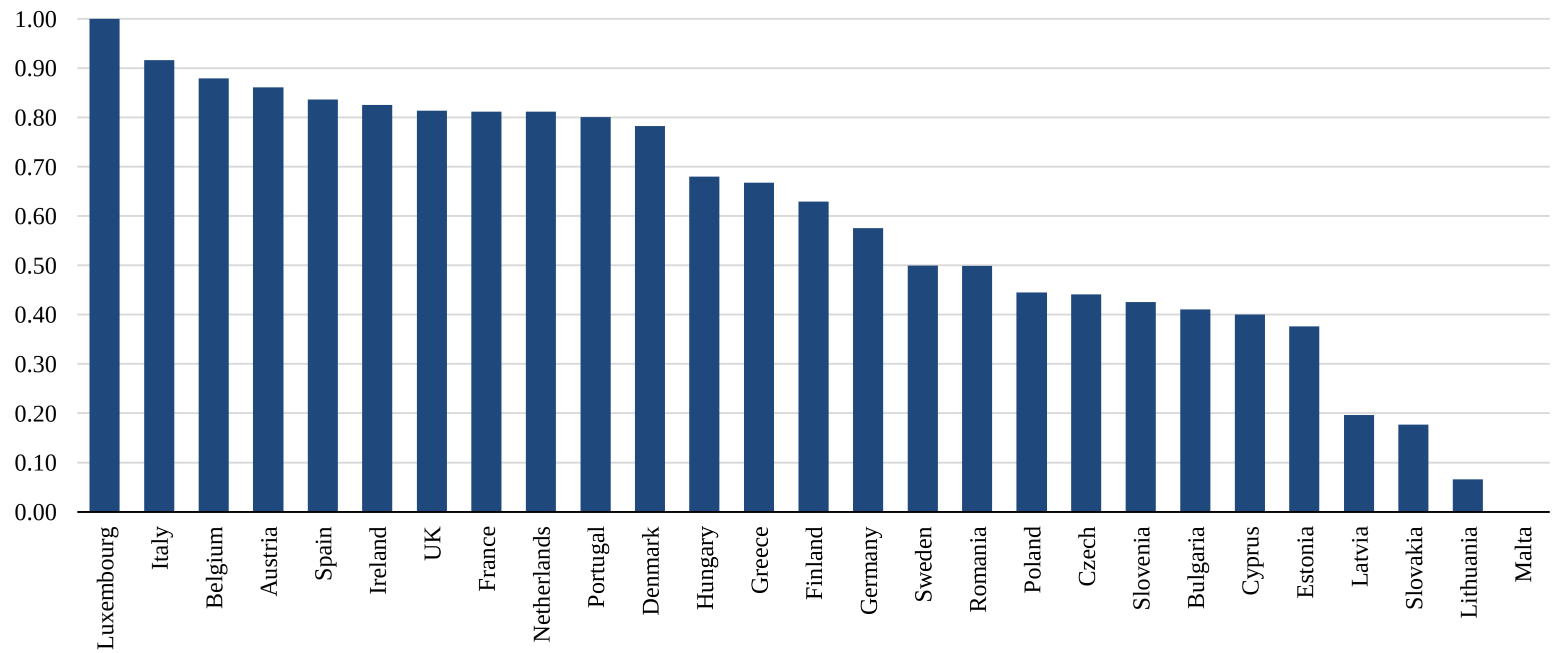
Notes: Identification is done according to Markov Switching models on the ADCC-GARCH Volatility series. The solid black line represents the crisis transition date. Crisis transition dates are: France: 09/08/2007; Czech Republic: 01/08/2007. Graphs for the remaining countries are omitted for brevity.

Figure 2. Crisis transition dates identified for the nations in the sample



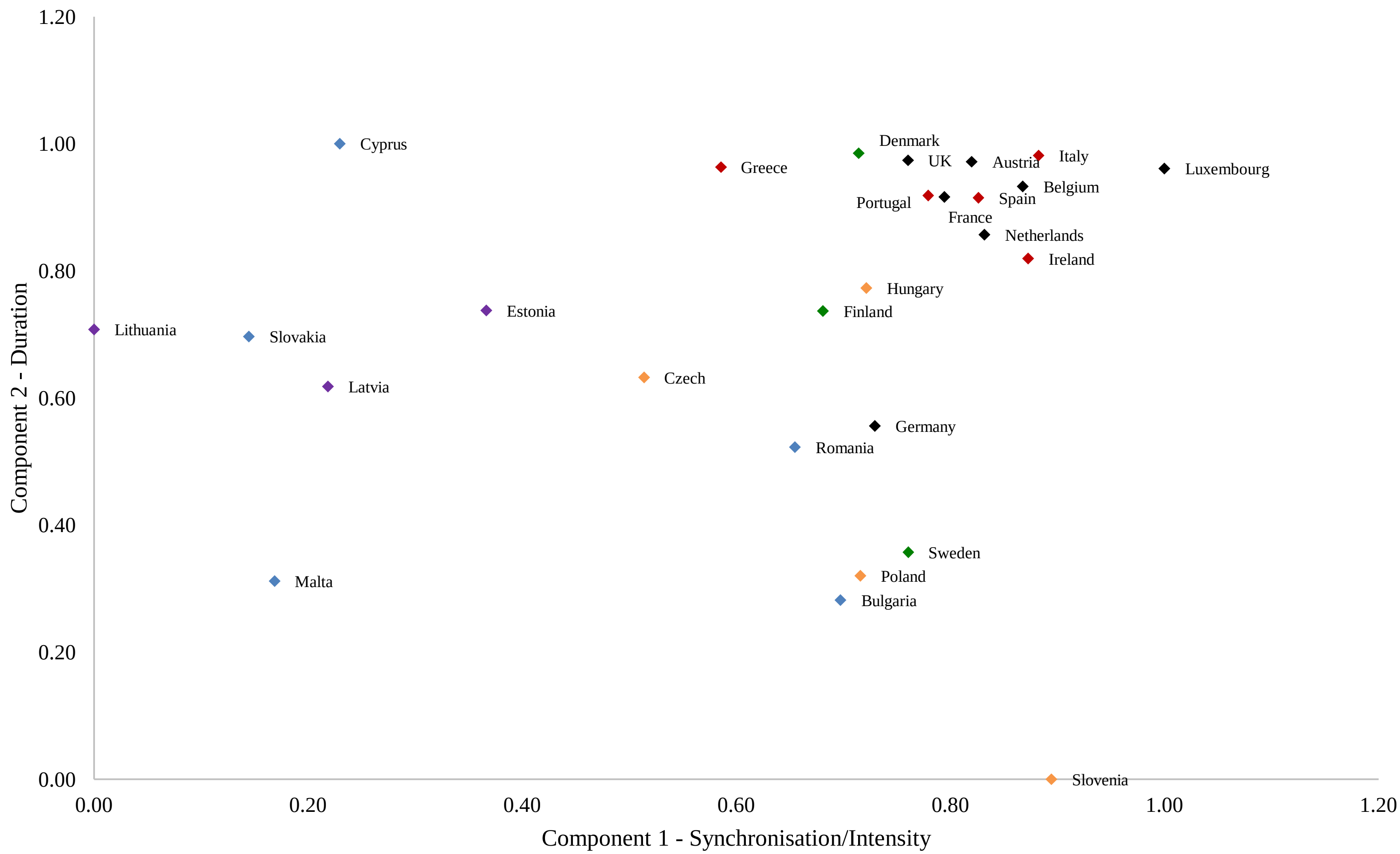
Notes: AUS=Austria; BEL=Belgium; BUL=Bulgaria; CYP=Cyprus; CZE=Czech Republic; DEN=Denmark; EST=Estonia; FIN=Finland; FRA=France; GER=Germany; GRE=Greece; HUN=Hungary; IRL=Ireland; ITA=Italy; LAT=Latvia; LIT=Lithuania; LUX=Luxembourg; MAL=Malta; NL=Netherlands; PL=Poland; POR=Portugal; ROM=Romania; SLVK=Slovakia; SLVN=Slovenia; SPA=Spain; SWE=Sweden; UK=United Kingdom.

Figure 3. Overall Crisis Ranking



Notes: The Overall Crisis Ranking measure is defined as the first principal component from the synchronisation, duration and intensity measures of the nations, and ranges between zero and one. Higher values indicate nations that had a more adverse crisis experience.

Figure 4. Nation classification using principal components for the crisis measures



Notes: The graph depicts the two retained principal components from the synchronisation, duration and intensity measures of the nations, and range between zero and one. Higher values indicate nations that had a more adverse crisis experience. Component 1 represents synchronisation/intensity and Component 2 captures duration of the crisis. Colour codes denote Scandinavian (green), Core EU (black), PIIGS (red), Baltics (purple), RAMS I (orange) and RAMS II (blue) groups.

Highlights

- We construct measures for the synchronization, duration and intensity of the crisis.
- We document evidence of a differentiated crisis experience across all EU members.
- We confirm the presence of financial contagion in five of the six nation groups.
- Not all of EU's stock markets enter the crisis at the same time.
- On average the nations of the EU-15 are affected earlier than the New Member States.